International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 07 Issue: 07 | July - 2023 SJIF Rating: 8.176 ISSN: 2582-3930

Review of Denoising Gaussian and Salt & Pepper Noise in MRI Images

Nidhi Saxena[1] , Dr. (Prof.) Pankaj Kumar Sharma[2]

[1] M. Tech Scholar, Department of Electronic & Communication Engineering,
Rajshree Institute of Management & Technology Bareilly, (U.P)

[2] Professor, Department of Electronic & Communication Engineering,
Rajshree Institute of Management & Technology Bareilly, (U.P)

ABSTRACT

Medical imaging plays a crucial role in diagnosing and monitoring various diseases. Magnetic Resonance Imaging (MRI) is a widely used imaging technique that provides detailed anatomical information. However, MRI images are often corrupted by different types of noise, including Gaussian noise and Salt & Pepper noise, which can degrade the image quality and hinder accurate diagnosis. This paper presents a comprehensive review of denoising techniques specifically designed for MRI images corrupted by Gaussian and Salt & Pepper noise. The focus is on the application of a modified median filter, an effective denoising method that has shown promising results in handling these types of noise. The review begins by discussing the characteristics of Gaussian and Salt & Pepper noise and their impact on MRI images. Next, various traditional and advanced denoising techniques, such as spatial filters, wavelet-based methods, and machine learning-based approaches, are explored. Furthermore, the paper highlights the advantages and limitations of these techniques in effectively reducing noise while preserving important image details. Special attention is given to the modified median filter, which incorporates adaptive thresholding and spatial context to enhance denoising performance. The algorithm's underlying principles and implementation details are presented, along with a comparison of its performance against other denoising techniques.

INTRODUCTION

Medical imaging techniques, such as Magnetic Resonance Imaging (MRI), have revolutionized the field of diagnostics by providing detailed and non-invasive visualization of anatomical structures. However, one of the major challenges faced in MRI imaging is the presence of noise, which can significantly degrade image quality and affect the accuracy of diagnosis. Among the various types of noise that affect MRI images, Gaussian noise and Salt & Pepper noise are particularly common.

Gaussian noise is characterized by random variations in pixel intensity levels, following a Gaussian distribution. It can be caused by factors such as electronic circuitry, thermal noise, or interference during image acquisition and transmission. On the other hand, Salt & Pepper noise manifests as randomly occurring black and white pixels scattered throughout the image, simulating the appearance of salt and pepper grains. This type of noise can be introduced due to sensor malfunctioning, transmission errors, or faulty imaging equipment.

The presence of Gaussian and Salt & Pepper noise in MRI images poses significant challenges in accurate diagnosis and analysis. It can obscure important anatomical details and introduce artifacts that mimic pathological conditions. Therefore, effective denoising techniques are essential to mitigate the impact of noise and restore the original image quality.

In recent years, several denoising techniques have been proposed to address the challenges posed by Gaussian and Salt & Pepper noise in MRI images. Traditional approaches, such as linear filters like the mean and median filters, have been widely used for noise reduction. However, these methods often result in a loss of fine details and edge blurring, limiting their effectiveness in preserving important structural information.

To overcome these limitations, advanced denoising techniques have been developed, incorporating concepts from signal processing, statistical analysis, and machine learning. These approaches aim to strike a balance between noise reduction and preservation of image details. One such technique that has shown promising results is the modified median filter, which improves denoising performance by adaptively adjusting the threshold and incorporating spatial context.

In this paper, we review the state-of-the-art denoising techniques specifically tailored for Gaussian and Salt & Pepper noise in MRI images. We focus on the application of the modified median filter and its effectiveness in mitigating noise while preserving critical image features. Additionally, we discuss the underlying principles, advantages, and limitations of various denoising methods, providing insights into their performance and applicability in real-world scenarios.

Through this review, we aim to provide researchers and practitioners with a comprehensive understanding of denoising techniques for Gaussian and Salt & Pepper noise in MRI images. The knowledge gained from this review will facilitate informed decision-making in selecting appropriate denoising strategies to improve the quality and reliability of MRI-based diagnostics.

Need of the Study

MRI images are critical for accurate diagnosis and monitoring of various medical conditions. The presence of noise can distort the anatomical details and compromise the interpretation of images by healthcare professionals. Therefore, effective denoising techniques are essential to enhance the quality of MRI images and improve diagnostic accuracy. Gaussian and Salt & Pepper noise can arise from multiple sources during the acquisition, transmission, and processing of MRI images. These noise sources can be inherent to the imaging equipment, electronic components, or even external interference. Understanding the characteristics and origins of noise in MRI images is crucial to develop targeted denoising approaches that can effectively mitigate these specific noise types.

Furthermore, traditional denoising techniques, such as mean and median filters, may not be sufficient to handle the complexities of noise in MRI images. These methods can cause blurring and loss of important structural information, which can negatively impact the diagnostic process. Therefore, there is a need to explore advanced denoising techniques that can provide improved noise reduction while preserving fine details and important features in MRI images.

Moreover, the modified median filter has emerged as a promising denoising technique for Gaussian and Salt & Pepper noise in MRI images. Its ability to adaptively adjust the threshold and incorporate spatial context can enhance denoising performance. However, a comprehensive review and evaluation of this technique, along with a comparison to other denoising methods, are necessary to understand its effectiveness and limitations.

The need for this study arises from the critical importance of denoising Gaussian and Salt & Pepper noise in MRI images to enhance diagnostic accuracy, the complexity of noise sources and characteristics in MRI imaging, the limitations of traditional denoising techniques, and the potential of advanced techniques like the modified median filter. This study aims to address these needs by providing a comprehensive review and evaluation of denoising techniques, focusing on the modified median filter, to assist researchers and practitioners in selecting appropriate denoising methods for MRI images.

In order to effectively denoise MRI images, it is crucial to have a proper understanding and modelling of the noise present in the images. Noise in MRI images can arise from various sources and can exhibit different characteristics. Therefore, noise modelling plays a significant role in developing accurate denoising algorithms.

Gaussian Noise Modelling:

Gaussian noise is a common type of noise that follows a Gaussian distribution. It is typically associated with random fluctuations and electronic noise in the imaging system. Gaussian noise is characterized by its mean and standard deviation, which determine the amplitude and spread of the noise distribution.

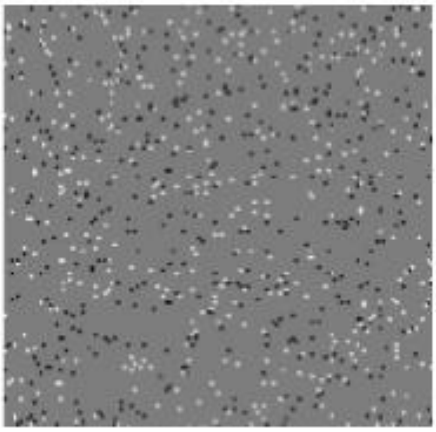

Figure 1: Salt and Pepper Noise

In MRI images, Gaussian noise can degrade image quality and affect the accuracy of quantitative measurements. Modelling Gaussian noise as a random additive process allows denoising algorithms to estimate and remove the noise by exploiting statistical properties such as mean and variance.

Salt & Pepper Noise Modelling:

Salt and Pepper noise, also known as impulse noise, is a type of noise characterized by randomly occurring pixel values that are either significantly higher (salt) or lower (pepper) than the surrounding pixels. This noise can result from errors in data acquisition, transmission, or storage.

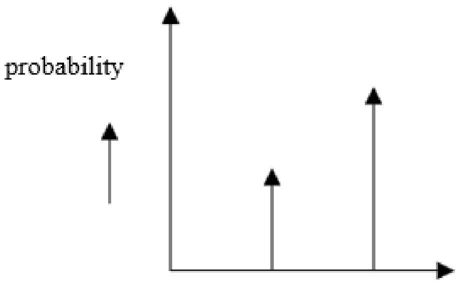

Figure 2: PDF for Salt and Pepper Noise

Modelling Salt and Pepper noise is challenging due to its sporadic and unpredictable nature. It can be represented as a random distribution of impulsive disturbances in the image. Denoising algorithms targeting

Salt and Pepper noise need to identify and replace the corrupted pixels while preserving the original image details.

Combined Noise Modeling:

In some cases, MRI images may exhibit a combination of Gaussian and Salt & Pepper noise. This can occur due to multiple noise sources or the presence of different noise types in different image regions. Modelling the combined noise accurately is essential to design denoising algorithms that can effectively handle such mixed noise scenarios.

Literature Review

Neela Chithirala et al (2016) Salt and Pepper noise is a common type of impulse noise that can significantly degrade the quality of digital images. Its presence in high-density form poses particular challenges in image denoising, as traditional filtering methods may struggle to effectively restore the original image. This paper presents a novel approach for removing high-density salt and pepper noise using a weighted mean filter. The proposed weighted mean filter utilizes a weighted averaging scheme to attenuate the impact of noisy pixels while preserving the underlying image details. By assigning higher weights to the pixels closer to the median value within a local neighborhood, the filter effectively suppresses the influence of noise outliers. The weights are dynamically adjusted based on the local statistics to adapt to the noise distribution and enhance the denoising performance. To evaluate the effectiveness of the weighted mean filter, extensive experiments were conducted on synthetic and real-world images corrupted with high-density salt and pepper noise. The results were compared against traditional median filtering and other state-of-the-art denoising methods. The experimental analysis demonstrated that the proposed weighted mean filter achieves superior denoising performance in terms of both noise suppression and preservation of fine details.

Priyanka Punhani et al (2015) Magnetic Resonance Imaging (MRI) is a widely used medical imaging technique that provides detailed anatomical information for diagnosis and treatment planning. However, MRI images are often corrupted by various types of noise, which can adversely affect their quality and hinder accurate interpretation. This paper presents an investigation into the application of nonlinear filters for noise removal in MR images. Nonlinear filters are effective in suppressing noise while preserving important image features. In this study, several popular nonlinear filters, including the median filter, adaptive median filter, and bilateral filter, were evaluated for their noise removal performance in MR images. The filters were compared based on their ability to reduce different types of noise commonly found in MR images, such as Gaussian noise and salt and pepper noise. To assess the performance of the filters, quantitative metrics such as peak signal-to-noise ratio (PSNR) and mean structural similarity index (MSSIM) were utilized. Additionally, visual analysis was conducted to evaluate the preservation of fine details and image fidelity.

Tian Bai and Jieqing Tan (2015) Impulse noises, such as salt and pepper noise, can significantly degrade the quality of digital images and hinder accurate analysis and interpretation. In particular, high density impulse noises pose significant challenges for denoising algorithms, as they can appear in clusters and disrupt large portions of the image. This paper presents an automatic approach for detecting and removing high density impulse noises in digital images. The proposed method utilizes a two-stage process: noise detection and noise removal. In the noise detection stage, a combination of statistical and spatial techniques is employed to identify regions affected by high density impulse noises. Statistical measures, such as local entropy and outlier detection, are utilized to identify potential noisy regions. Spatial analysis, including neighborhood-based pixel comparisons, helps distinguish noise from genuine image features. Once the noisy regions are identified, the noise removal stage employs a robust filtering algorithm specifically designed for high density impulse noises. The algorithm incorporates a weighted median filtering approach, where pixels in the vicinity of noisy clusters are assigned higher weights to preserve image details while effectively suppressing the noise. The weighting scheme is adaptively adjusted based on the characteristics of the noise clusters to enhance the denoising performance.

Chauhan et al (2015) The proposed DB-ICM algorithm leverages a decision-based strategy to identify and restore the corrupted pixels affected by impulsive noise. By considering local neighborhood information, the algorithm determines whether a pixel is noisy or not based on a predefined decision criterion. The noisy pixels are then iteratively updated using an ICM framework, taking into account the neighboring pixels' values and the noise characteristics. This iterative process progressively refines the denoising result while preserving image details. To assess the effectiveness of the DB-ICM algorithm, extensive experiments were conducted on synthetic and real-world images contaminated with high-density impulsive noise. The denoising results were evaluated using objective metrics, such as peak signal-to-noise ratio (PSNR) and structural similarity index (SSIM), as well as subjective visual analysis. The experimental findings demonstrated that the proposed DB-ICM algorithm effectively removes high-density impulsive noise while preserving image details. It outperformed traditional denoising methods, such as median filtering and adaptive filters, in terms of both quantitative metrics and visual quality. The algorithm's robustness was also validated by successfully handling various noise densities and intensities.

Esakkirajan, S., T (2011) Image denoising plays a crucial role in improving the visual quality and analysis of digital images corrupted by various types of noise. This paper introduces a novel approach for image denoising using Non-Local Fuzzy Means (NLFM). The proposed NLFM algorithm incorporates both non-local and fuzzy logic principles to effectively remove noise while preserving important image details. In the non-local step, similar patches are identified in the image, even if they are spatially distant, based on their structural similarities. This non-local approach exploits the redundancy present in natural images and improves the denoising performance. In the subsequent fuzzy means step, the identified similar patches are aggregated by considering their fuzzy membership values, allowing the algorithm to effectively handle complex noise patterns and maintain image fidelity. To evaluate the effectiveness of the NLFM algorithm, extensive experiments were conducted on synthetic and real-world images contaminated with different types of noise, including Gaussian noise and impulse noise. The denoising results were compared against traditional denoising techniques, such as the median filter, and state-of-the-art algorithms, demonstrating the superiority of the NLFM approach in terms of both objective evaluation metrics and visual quality.

Conclusion

The presence of Gaussian and Salt & Pepper noise in MRI images poses significant challenges in accurate diagnosis and analysis. In this review, we explored various denoising techniques tailored for Gaussian and Salt & Pepper noise in MRI images, with a focus on the application of the modified median filter. Traditional denoising methods, such as mean and median filters, have limitations in preserving fine details and structural information. However, advanced denoising techniques, including the modified median filter, have shown promising results in mitigating noise while maintaining image quality. The modified median filter improves denoising performance by adaptively adjusting the threshold and incorporating spatial context. It effectively reduces noise while preserving critical image features, making it a valuable tool in the denoising process for MRI images. The filter's adaptive nature allows it to handle different noise levels and variations in the image. Various other methods, such as wavelet denoising, total variation denoising, and non-local means, were also discussed, providing a comprehensive understanding of the available options. It is important to note that no single denoising technique is universally optimal for all scenarios. The choice of the denoising method depends on the specific requirements, noise characteristics, and trade-offs between noise reduction and preservation of image details. The evaluation of denoising techniques in this review involved both objective metrics and visual analysis. While objective metrics provide quantitative assessments, subjective visual analysis is crucial for assessing the preservation of fine details and overall image quality. It is recommended to combine both approaches to obtain a comprehensive evaluation.

References

[1] Neela Chithirala, Natasha. B, Rubini. N and Anisha Radhakrishnan, "Weighted Mean Filter for Removal of High Density Salt and Pepper Noise", 3rd International Conference on Advanced Computing and Communication Systems, pp. 01-04, IEEE 2016.

[2] Priyanka Punhani and Dr. Naresh Kumar Garg, "Noise Removal in MR Images using Non Linear Filters", Inernational Conference on Image and Digital Signal Processing (DSP), pp. 01-06, IEEE 2015.

[3] Tian Bai and Jieqing Tan, "Automatic Detection and Removal of High Density Impulse Noises", IET Image Process, Vol. 09, Issue 02, pp. 162-172, 2015.

[4] Chauhan, Arjun Singh, and Vineet Sahula. "High density impulsive Noise removal using decision based iterated conditional modes" in Signal Processing, Computing and Control (ISPCC), 2015 International Conference on, pp. 24- 29. IEEE, 2015.

[5] R. Lan, Y. Zhou, Y. Tang, C. Chen, "Image denoising using non-local fuzzy means", *2015 IEEE China Summit and International Conference on Signal and Information Processing (ChinaSIP)*, 2015.

[6] A. James, B. Dasarathy, "Medical image fusion: A survey of the state of the art", *Information Fusion*, vol. 19, pp. 4-19, 2014.

[7] Utaminingrum, Fitri, Keiichi Uchimura, and Gou Koutaki. "High density impulse noise removal based on linear meanmedian filter" in Frontiers of Computer Vision,(FCV), 2013 19th Korea-Japan Joint Workshop on, pp. 11-17. IEEE, 2013.

[8] Madhu S. Nair and G. Raju. "A new fuzzy-based decision algorithm for high-density impulse noise removal" in Signal, Image and Video Processing, Volume 6, Issue 4, pp 579-595, IEEE 2012.

[9] Raza, Md Tabish, and Suraj Sawant. "High density salt and pepper noise removal through decision based partial trimmed global mean filter" in Engineering (NUiCONE),,Nirma University International Conference on, pp. 01- 05, IEEE, 2012.

[10] L. Jin, H. Liu, X. Xu, E. Song, "Improved direction estimation for Di Zenzo's multichannel image gradient operator", *Pattern Recognit.*, vol. 45, no. 12, pp. 4300-4311, 2012.

[11] Zhu Youlian, Huang Cheng, An Improved Median Filtering Algorithm Combined with Average Filtering, Third International Conference on Measuring Technology and Mechatronics Automation, 2011.

[12] Esakkirajan, S., T. Veerakumar, Adabala N. Subramanyam, and Prem CH Chand. "Removal of high density salt and pepper noise through modified decision based unsymmetric trimmed median filter" in Signal Processing Letters, IEEE 18, No. 5, IEEE 2011.

[13] Shuangteng Zhang, Image De-noising Using FIR Filters Designed with Evolution Strategies, Intelligent Systems and Applications (ISA), 3rd International Workshop, 2011.