International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 09 Issue: 08 | Aug - 2025 SJIF Rating: 8.586 ISSN: 2582-3930

Comparative Analysis of Noise Reduction Techniques for Brain MRI Images

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Abstract - Comparative analysis of noise reduction techniques for brain MRI images delves into the evaluation of various noise types, including salt and pepper, gaussian, and speckle noise. This study considers three prominent filters: the median filter, non-local means (NLM) algorithm, and gaussian filter, along with performance metrics such as Peak Signal-to-Noise Ratio (PSNR), Structural Similarity Index (SSIM), Mean Squared Error (MSE), and Entropy. When confronted with salt and pepper noise, the Non-Local Means (NLM) filter excels, reducing noise with minimal information loss. However, Visual inspection favors the median filter for effective noise reduction. For speckle noise, a comprehensive assessment combining quantitative analysis and visual inspection favors the NLM algorithm, showcasing its noise reduction capabilities without compromising image information. In the case of gaussian noise, quantitative analysis underscores the NLM filter's ability to achieve high PSNR values, emphasizing its proficiency in noise reduction, though with noticeable smoothening. For Gaussian filter, while blurring the image, retains information effectively. In summary, the NLM filter is robust for speckle and gaussian noise, excelling quantitatively and visually, while the median filter is preferred for salt and pepper noise when preserving image details is crucial. This analysis provides insights for informed decision-making in enhancing brain MRI image quality.

***Key Words*:** MRI image, Filtering, Median filter, Non local means algorithm, Gaussian filter.

1.INTRODUCTION

Brain tumor detection plays a pivotal role in the field of medicine, and the utilization of MRI images has significantly enhanced this process. It is imperative to emphasize the importance of this detection technique in identifying brain tumors accurately and efficiently. MRI, an abbreviation for Magnetic Resonance Imaging, is a non-invasive imaging modality that uses a strong magnetic field and radio waves to produce detailed images of the brain. The significance of MRI in brain tumor detection lies in its ability to provide a comprehensive view of the brain's structure, as well as the presence and characteristics of any abnormal growths.

This diagnostic tool enables healthcare professionals to detect brain tumors at their earliest stages, facilitating timely intervention and treatment planning. Furthermore, MRI images assist in precisely locating the tumor, determining its size, and assessing its impact on surrounding brain tissues, ultimately guiding surgeons in their decision-making process. By utilizing MRI for brain tumor detection, healthcare providers can offer accurate diagnoses, personalized treatment strategies, and improved patient outcomes. Thus, the integration of MRI imaging in the medical field proves essential in the early detection and subsequent management of brain tumors.

Magnetic Resonance Imaging (MRI) has become an indispensable tool in the medical field, revolutionizing the way we diagnose and understand conditions of the brain. This advanced imaging technique uses a powerful magnetic field and radio waves to create detailed images of the brain, allowing healthcare professionals to visualize its structures and identify abnormalities with exceptional precision. The importance of MRI brain images lies in their ability to provide crucial information regarding the presence and progression of various neurological disorders such as tumors, strokes, and degenerative diseases.

By capturing clear and detailed images of the brain, MRI enables healthcare providers to make accurate diagnoses, plan appropriate treatment strategies, and monitor the effectiveness of interventions. The simplicity of the MRI technique, coupled with its unparalleled ability to offer insights into the complex workings of the brain, has undoubtedly cemented its position as an invaluable tool in the medical field. With ongoing advancements and a growing understanding of its capabilities, MRI continues to transform the way neurologic conditions are diagnosed and managed, enhancing patient care and improving outcomes.

Magnetic Resonance Imaging (MRI) stands as a cornerstone in contemporary medical diagnostics, offering unparalleled insights into the intricate anatomical and physiological details of the human body without the use of ionizing radiation. Despite its indisputable clinical significance, the fidelity of MRI images is inevitably compromised by the omnipresent challenge of noise. This pervasive interference manifests from a plethora of sources, spanning the electronic intricacies of the imaging apparatus to intrinsic physiological nuances of the human body undergoing examination.

Electronic noise, originating from the complex interplay of radiofrequency signals and electronic components, introduces random fluctuations that can distort image quality. Concurrently, motion artifacts induced by patient movements, whether voluntary or in voluntary, contribute to the degradation of spatial resolution and overall image clarity. Furthermore, physiological processes, such as cardiac pulsations and respiratory cycles, introduce temporal variations in the acquired signals, leading to temporal artifacts that manifest as unwanted signal variations. This multifaceted nature of noise poses a formidable challenge to the field of MRI, demanding a nuanced understanding of its diverse origins and implications for diagnostic accuracy.

2. METHODOLOGY

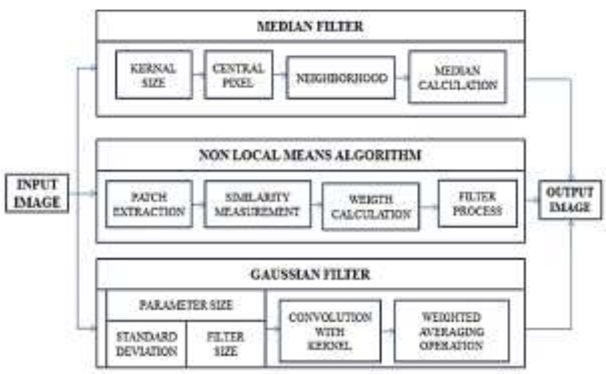

Fig – 1: Block diagram for proposed system

This block diagram designed to reduce the impact of salt and pepper, speckle, and Gaussian noise in a systematic and multi-step approach to enhance image quality. At the initial stage, the MRI brain image, inherently susceptible to various forms of noise, serves as the input image. This input image, contaminated with intensity spikes (salt and pepper noise), granular patterns (speckle noise), and subtle variations (Gaussian noise), undergoes a series of filtering steps. The first filter applied is the median filter, adept at suppressing the noise by replacing each pixel value with the median value of its local neighborhood. The second filter is Non-local Means algorithm, a sophisticated denoising technique. The Non-local Means algorithm excels in preserving structural details while effectively suppressing noise. Third filter, the image undergoes through a Gaussian filter, by convolving the image with a Gaussian kernel. This multi-faceted approach not only reduces the impact of specific noise types but also ensures a balanced preservation of essential image features.

3. RESULTS AND DISCUSSION

Experimental results and discussion are explained in this chapter. A brief description of implementation is given below. First the input image is taken from customised noisy MRI dataset; the input image is taken as .jpg format. Filters are used to remove the noise. Then the images are compared on the basis of quantitative metrics and visual inspection.

SALT AND PEPPER NOISE

The salt and pepper noisy image is filtered using a median filter. Which is visually effective in reducing noise without lossing the information but results in a smoother image.
The Non Local Means filter effectively reduces noise in the image. Showcasing a significant reduction in noise levels with minimal information loss. The edges remain clear; however, it appears there may be a slight oversmoothing effect on the image.
The salt and pepper noise is reduced using a median filter. The noise is not completely eliminated, and it also blurs the image.

SPECKLE NOISE

The speckle noise is reduced using a median filter. While the filtered image successfully reduces noise, it also exhibits some blurring, indicating a compromise with potential information loss.
The non-local means filter is employed to reduce speckle noise. Showcasing a denoised result without compromising essential information in the MRI image.
The Gaussian filter effectively filters noise, it simultaneously introduces blurring, resulting in the loss of fine details and edges in the image.

GAUSSIAN NOISE

Gaussian noise is mitigated using a median filter. However, the visually evident result indicates that the noise reduction is not effective, and, in addition, the image quality is compromised with noticeable blurring and loss of information.
The NLM filter is applied to reduce noise in the MRI image. The resulting image demonstrates effective noise reduction without significant loss of information. However, it is worth noting that the image appears to be over-smoothed.
The Gaussian filter is employed to reduce noise in the MRI image. The resulting Gaussian-filtered image effectively removes noise, providing clear edges. However, it is important to note that the image also exhibits some blurring.

4. CONCLUSION

In conclusion, for salt and pepper noise, the Non-Local Means (NLM) filter demonstrates a commendable reduction in noise levels with minimal information loss. However, visual inspection suggests that the median filter is effective in noise reduction and with a smoother resultant image. In the case of speckle noise both quantitative analysis and visual inspection unanimously favor the NLM algorithm, shows superior noise reduction capabilities without sacrificing image information. For Gaussian noise, quantitative analysis indicates that the NLM filter achieves high Peak Signal-to-Noise Ratio (PSNR) values, emphasizing its proficiency in noise reduction. However, the accompanying observation notes that this comes at the expense of smoothening the image. On the other hand, the Gaussian filter, while blurring the image, manages to retain information effectively. In summary, The NLM filter emerges as a robust option for speckle and Gaussian noise, excelling in both quantitative metrics and visual assessment, while the median filter may be preferred for salt and pepper noise when preserving image details is paramount.

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