Enhancing MR Image Quality for Accurate Rectal Cancer Diagnosis: A Comparative Study of Preprocessing Techniques

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Abstract.
Rectal cancer is a rapidly growing health concern worldwide. Magnetic resonance (MR) imaging plays a pivotal role in accurately staging rectal cancer by providing detailed anatomical and pathological information. Preprocessing involves denoising, contrast enhancement, and normalization techniques to improve image quality for the development of a robust computer-aided diagnosis system. In this study, five preprocessing filter combinations Gaussian-Mean-Median, Gaussian-Mean-Maximum, Gaussian-Mean-Minimum, Gaussian-Median-Maximum, and Gaussian-Median-Minimum were applied to enhance the quality of MR images. Statistical metrics, including PSNR, SSIM, MSE and RMSE were employed to evaluate the performance of these techniques. The analysis was conducted on a dataset acquired from Kasturba Medical College, Manipal. Among the tested methods, the Gaussian-Mean-Median filter demonstrated superior performance.

Keywords- Magnetic Resonance Images, Peak Signal-to-Noise Ratio, Structural Similarity Index Measure, Mean Squared Error, and Root Mean Squared Error.

1. INTRODUCTION

Rectal cancer is a type of cancer that develops in the rectum, which is the final part of the large intestine. It is closely related to colon cancer and is often grouped under the term colorectal cancer [1]. The staging of rectal cancer is based on TNM system, which assesses the extent of the tumor (T), the involvement of lymph nodes (N), and the presence of metastasis (M) [2].
Computer-aided diagnostic (CAD) systems is used to assist in the detection and diagnosis of rectal cancer. These systems leverage advanced imaging techniques, such as MRI, CT scans to identify abnormal tissue and assess the extent of the disease. MRI is a crucial tool in detecting and diagnosing rectal cancer due to its excellent soft tissue contrast and high-resolution capabilities [3]. CAD systems can automatically identify suspicious areas in medical images, reducing the likelihood of missing small or subtle lesions [4].

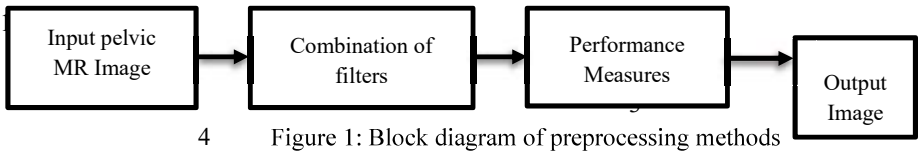
2. LITERATURE REVIEW

Suhas et.al. [5] developed a method that enhances the existing median filter by incorporating additional features. The filtering algorithms like Median, Max, Min, Gaussian and Arithmetic Mean filter were then used to examine the experimental results. Statistical metrics such as SNR, PSNR and root mean square error (RMSE) were employed. Srivaramangai et.al. [6] proposed pre-processing methods for image enhancement and noise reduction. Statistical parameters like Signal to Noise Ratio (SNR), Features Similarity Index Matrix (FSIM), PSNR, AMBE, CNR, and MSE and are used to measure the image enhancement. Adaptive median filters, mean and median filters are used to remove noise. MSE and PSNR are used to determine the ideal filter. D.N. Lohare et.al. [7] suggested a method for pre-processing the brain tumor image using techniques for image enhancement and noise reduction. Gaussian high pass filter is used to improve input image and filters are used to extract noise

from the slice in order to sharpen the image. A. Thangaraju et.al. [8] implemented various de-noising techniques, including Mean Filter, Gaussian Filter, Kalman Filter, and Alpha-Trimmed Mean Filter were evaluated using metrics like SSIM, PSNR and MSE. Results highlight ATMF's superior performance. Nagaraja et.al. [9] combined Wiener and Median filtering. MRI are first denoised using the Wiener filter and then enhanced with a Median filter. Results of proposed method demonstrated that it outperformed in terms of MSE, PSNR, and SSIM for Gaussian, Rician, and combined noise. N. Senthilkumaran et.al [10] proposed an automated approach combining a hybrid CLEACH-Median filter algorithm for contrast enhancement and a hybrid salient segmentation method with K-Means clustering for feature extraction and segmentation. P. Harish et.al. [11] Median-Anisotropic filter is used during preprocessing to eliminate noise while preserving image edges. A.S. Thanushree et.al. [12] Preprocessing techniques like grayscale conversion, Top Hat filtering, and watershed transforms were used.

3. METHODOLOGY

Preprocessing of MR Images is performed to enhance image quality by reducing noise, improving contrast, and preserving essential anatomical details. A combination of spatial domain filters like Gaussian, Mean, Median, Maximum, and Minimum filters is applied to achieve optimal image enhancement. The various filter combinations applied are Gaussian-Mean-Median enhances smoothness while preserving edges by removing noise effectively. Gaussian-Mean-Minimum smooths the image while enhancing darker regions, improving contrast for better boundary detection. Gaussian-Mean-Maximum enhances bright regions while reducing noise, making anatomical structures more distinct. Gaussian-Median-Maximum effectively removes impulse noise while emphasizing brighter areas, aiding in the identification of key features and Gaussian-Median-Minimum reduces noise while enhancing darker structures, improving the clarity of boundaries and textures.

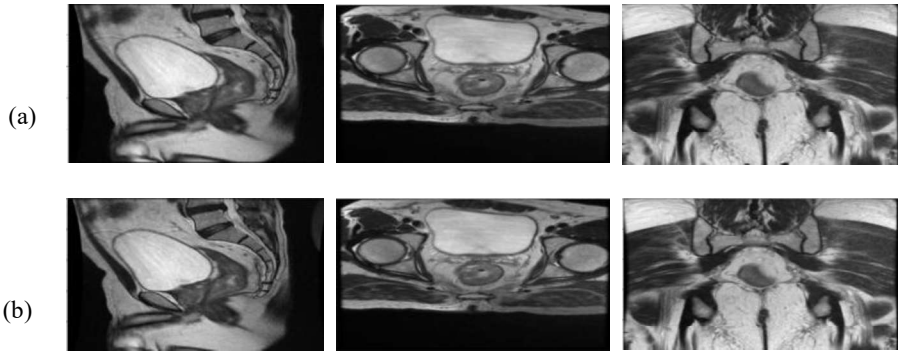


4 Figure 1: Block diagram of preprocessing methods

5 The Gaussian-Mean-Median combination demonstrated superior performance in maintaining both image clarity and structural details. Statistical parameters such as RMSE, MSE, SSIM, and PSNR were evaluated as shown in fig 1.

4. RESULT AND DISCUSSION

This section presents the findings from applying five preprocessing filter combinations Gaussian-Mean-Median, Gaussian-Mean-Maximum, Gaussian-Mean-Minimum, Gaussian-Median-Maximum, and Gaussian-Median-Minimum on MR images from the dataset acquired at KMC, Manipal as shown in figure 2. The evaluation of these filter combinations was carried out using four statistical metrics: PSNR, MSE, RMSE and SSIM.



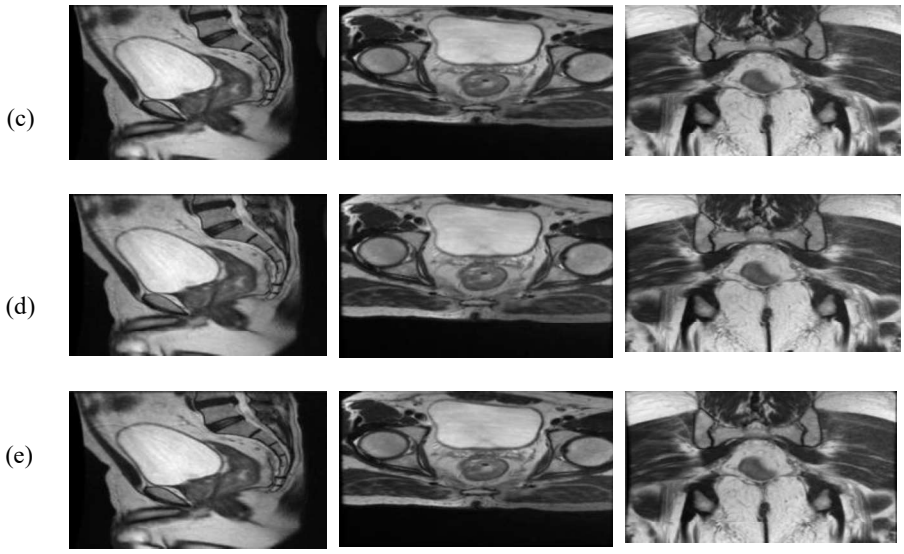


Figure 2: Results obtained from different combination of filters (a) Gaussian-mean-median (b) Gaussian-Mean-Maximum (c) Gaussian-Mean-Minimum (d) Gaussian-Median-Maximum (e) Gaussian-Median-Minimum.

These combined filters were specifically used because of its effectiveness in addressing different types of noise in digital images. The combined result of these filters provides a balanced approach to noise reduction, ensuring both noise suppression and preservation of important image details as shown in table 1.

Table 1: statistical parameters obtained from the various combination of filters

Filter Methods	MRI View	PSNR	SSIM	MSE	RMSE
Guassian-Mean-Median	Sagittal View	61.16	0.93	3.05	0.0017
	Coronal View	53.74	0.89	4.21	0.002
	Axial View	59.08	0.93	4.94	0.002
Gaussian-Mean-Maximum	Sagittal View	60.46	0.92	3.59	0.001
	Coronal View	53.27	0.89	4.70	0.002
	Axial View	58.54	0.92	5.59	0.002
Gaussian-Mean-Minimum	Sagittal View	60.87	0.93	3.26	0.001
	Coronal View	53.60	0.89	4.36	0.002
	Axial View	58.12	0.92	6.15	0.002
Gaussian-Median-Maximum	Sagittal View	53.66	0.92	4.29	0.002
	Coronal View	52.45	0.88	5.67	0.002
	Axial View	52.01	0.92	6.28	0.002
Gaussian-Median-Minimum	Sagittal View	55.20	0.93	3.01	0.001
	Coronal View	53.89	0.89	4.07	0.002
	Axial View	52.71	0.93	5.35	0.002

5. CONCLUSION

Rectal cancer poses significant challenges in early detection and staging, making high-quality MR imaging crucial for accurate diagnosis. This study evaluated five preprocessing filter combinations on a dataset acquired from KMC, Manipal. Among these, the Gaussian-Mean-Median filter demonstrated superior performance in noise reduction and structural preservation, as confirmed by PSNR, SSIM, MSE, and RMSE metrics. In the future, the preprocessed images can be utilized for segmentation, enabling more detailed analysis and advancing rectal cancer staging and treatment planning.

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