A Review of Brain MRI Image Enhancement Techniques

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Abstract. An important step in analyzing information about brain images is image processing. Electromagnetic resonance imaging (MRI) images constitute essential details that the clinicians need to detect disease and make the suitable treatment. To improve the quality of the input images, image preprocessing is the initial stage in image processing technology. Artifact removal, skull removal, noise reduction, and image quality enhancement are among the image preprocessing steps. Images need to be processed to quickly detect tumors. The aim of this study is to provide an overview of present techniques for improving the feature of MRI images and to determine the advantages and disadvantage of every technique for further advance tumor detection. Considering the advantages and disadvantages of each approach, the ideal way to treat a variety of different cases will be chosen. After a brief introduction, a table summarizing each method is presented. In this study, the intensification (INT) operator was found to be the best preprocessing technique for the clinical dataset with the maximum PSNR value of 100 and the lowest RMSE value of 0.0747. Meanwhile, the Non-Local Means Filter has the minimum Mean- square error value of 0.0250 among the other enhancement techniques for the clinical datasets.

Keywords: Enhancement methods · Brain MR image · noise reduction · performance parameter

1 Introduction

Humans can be affected by numerous diseases. Some of them may damage the outer part of human body, while others may damage other major vital organs, which leads to end of human life.

The National Cancer Registry Programme data showed a total number of 13,92,179 in 2020, and the mortality rate increased by 16 PCBRs (population-based cancer registries). The approach of this study can be used to examine the status and trends of cancer in India. In this way, it can be determined how best to support initiatives to promote cancer prevention and control [1].

Scanning the body can find the majority of cancers that affect internal organs. Recently, several techniques have been improved to examine body tissues, including Computed tomography, X-rays, digital mammography, and also MRI. Though, the fact

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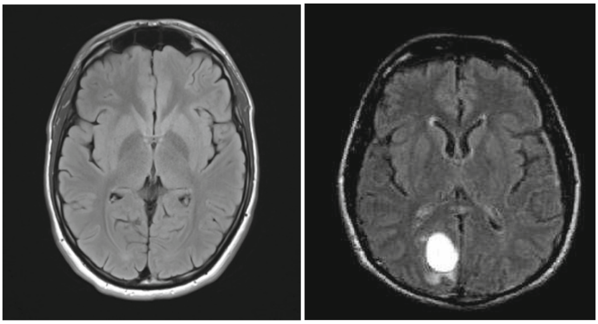

(i) (ii)

Fig. 1. (i) Brain MRI image without tumor; (ii) Brain MRI image with tumor.

that MRI does not release ionizing radiation offers a number of advantages. This is generated during CT scans and is very harmful to the body [2].

To diagnose anatomical diseases using artificial intelligence (AI) systems, physicians often use the results of MRI scans. Still, the results of the MRI scan don't directly bring conclusions of the complaint.Numerous techniques have been developed for processing MRI images to aid in the rapid detection of disease.

Improving image quality is the first step in diagnosing a disease. This is followed by feature extraction, segmentationand disease identification.Improving the image quality not only helps to save the original image data of the patient, but also reduces the various types of noise in the input images, so that the specific facts about the examined object are preserved in their original state. Histograms have been used in some research studies to enhance the quality of MRI images of the brain [12–14]. Mouna Sahnoun et al. suggested gamma correction as one of the simplest methods to improve the brightness of MRI images [9].

Randeep Kaur et al. (2020) proposed a fuzzy logic-based image enhancement technique. In this study, the intensification operator, fuzzy type I and fuzzy type II approaches are used. The INT is an enhancement operator that reduces the blur of an image. Blur means that the pixels appear dull. This method includes various parameters to evaluate the enhancement of digital images [15] (Fig. 1).

Some studies to enhancethe quality of MR images of the brain have been performed using linear and nonlinear filters [5–8, 10], gamma correction [9], and histogram techniques [12–14]. The analysis of this study focuses on techniques useful for preprocessing medical images of the brain.

2 Literature Review

After acquiring the necessary data consisting of MRI images, image processing can begin. The noise present in the original MRI image are then eliminated during preprocessing. This review deals with the MRI input images and the image noise will be processed later.

2.1 MRI Images

MRI is used in radiological investigative tests. Using the fluctuation resonance in the midpoint of a hydrogen particle and magnetic fields between 0.064 and 1.5 Tesla (1 Tesla = 1000 Gauss), cross-sectional images of the human body and organs are obtained [3].

Axial, sagittal, coronal, and oblique sliced images can be displayed on an MRI without significantly affecting the patient's position in the anatomy. As a result, it is appropriate for soft tissue imaging. The approach to MRI imaging is quite comprehensive, as many parameters affect the final image. If the standards are selected properly, the MRI scan provides a detailed picture of body organs with contradictory variations. Since the patient's body organs cannot be controlled, the organs and genetics of the body tissue can be accurately observed and calculated [3].

2.2 Images Noise

Deepa B et al. compared enhancement methods for medical images. Images captured by sensors, scanning circuits, or cameras may have noise, which is random variation in the colour or brightness of the information. It may come from the required noise that is always present in an ideal photon detector, or from film grain. This image noise is an unpleasant by-product of the capture process. The tools used for acquisition, the media used for information exchange, the image quantization, and discrete radiation source technique are all factors that determine how noise is reflected in the images. Rician noise is impressed on MRI images, while Gaussian noise affects normal images [4].

3 Image Enhancement Methods

In this section, the several techniques for preprocessing MRI images are presented. Some techniques that have been commonly used in previous studies are discussed and summarized.

3.1 Median Filter

The median filter approach to image preprocessing has been used in numerous studies. They combined the median filter method with other techniques that use standard median filters.

In a study published in 2017, Anitha S et al. compared the values of PSNR, MSE, and RMSE, obtained using the median filter and the Wiener filter on MRI input images of the brain. According to the results, the median filter outperforms its competitors. Images with the median filter have better pixel quality than images with the Wiener filter in terms of MSE, RMSE, and values of Peak Signal to Noise Ratio [5].

However, to enable a correct diagnosis, a 2017 study by SuhasS et al. attempts to eliminate noise and increase visual contrast. This study is an evolution of the previous study [5], but lacks many details. Therefore, the current study aims to use a hybrid technique to obtain the complicated information in the image. The, mean filter, midpoint filter and median filter were incorporated into the study [6]. This combination method was chosen because it produces MRI images that are more accurate and preserve detailed image information better than before the combination. The result of the study show that this strategy effectively reduces noise while preserving the structural features of the image.

Similar research was conducted in 2017 [7] "to improve the quality of MRI input images to facilitate the segmentation of brain components and the detection of brain cancers. Although a previous study [6] was able to maintain accurate image information, the three approaches together resulted in longer computation time, making them less suitable for real-time situations. Therefore, only the median filter, and the Wiener filter were combined in this study. The result of this study showed that the proposed technique had improved image accuracy, as measured by the values of PSNR and MSE, compared to the median and Wiener filters".

3.2 ATM - Alpha Trimmed Mean Filter

Shakunthala, M., et al. investigated the application of the ATM Filter in 2019. To accurately diagnose the image to be improved, this study compares the best image quality results. This study is an extension of the study [11], which runs faster and retains more information in the initial image. The input image was subjected to a series of filters to obtain the calculated values of Mean Square Error and PSNR. The end result showed that, the ATM filter performed better than the output image in terms of MSE and PSNR [8].

3.3 Adaptive Gamma Correction (AGC)

It has also been used to modify traditional techniques such as AGC for preprocessing MRI images [9]. The aim of this study is to improve the input images' visual quality so that they are better suited for analysis and human concepts. When compared to the AGC approach, which improves brightness, structure protection, and image quality, the results showed that the TGC technique determines the best values of SSIM, EWE, AMBE, and PSNR, particularly for gamma = 1.1, but the AGC approach preserves image details better when comparing the best values for QRCM and entropy. The classification of the input photos as low or high contrast led to this increase.

3.4 NLM (Non-Linear Means) Filter

In a study [10], an effort is made to find nonlinear noise - reducing methods and noise models for MRI brain images.The NLMF technique was used. The outcome suggests that NLM Filters propose enhanced MSE, SSI and Peak Signal to Noise Ratio values for Gaussian brain MR input images, though the mean NLMF implementation time is longer. The objective of future development of NLMF is to speed up the calculation time.

3.5 Homomorphic Filter

In a study [11], a filtering method was used to improve the shape of the tumor image. Homomorphic filter was used in the study because it needs minimal human involvement and will be helpful in several other areas where the selection phase is a difficult process. The result has a lowest MSE (close to zero) and a maximum PSNR, according to the findings. Thus, since the brain tumor is obviously noticeable in the MRI image, it can be said that homomorphic-filters are preferable fortumor identification because the segmentation process is increased successful.

3.6 AHE - Adaptive Histogram Equalization

The research [12] of 2018 paper compared different contrast-enhancing techniques for MRI brain cancers to enhance the important image content through noise removal while keeping the existing detailed features. AHE techniques were used in the study. This technique is a further growth of the basic HE method, in which the contrast of the input image to be processed is increased by adjusting the image to be processed. The outcomes show that the AHE technique provides effective performance for increasing MRI contrast, unlike previous techniques.

3.7 AIR-AHE (Average Intensity Reinstatement Placed on Adaptive Histogram Equalization)

Research [13] presented in 2016 toenhancethe quality of input MR input images of the brain using the AIR-AHE approach. The higher WMH contrast obtained with this method is the maximum, which is why the study uses it [13]. Similar to that study [12], the strategy used in this study to automatically improve the contrast and intensity of each MRI image is a version of the basic method known as HE. In this study, it is shown that how feature images increase in importance and how image contrast increases. Hence, the WMH region can be divided with the help of improved mathematical and morphologicalsets.

3.8 BPDFHE - Brightness Preserving Dynamic Fuzzy Histogram Equalization

In 2017, study [14] compared the improved quality of image enhancements such as artifact removal, skull removal, and noise decrease with different filtering techniques. Using BPDFHE techniques. The approach used in this study is similar to that of researchers [13, 14] in that it modifies the histogram equalization technique using fuzzy logic to overcome image uncertainties and preserve the brightness and enhance the contrast in output image while dropping the computational difficulty. The outcomes indicated that BPDFHE's MSE and RMSE values are lesser than its PSNR values. This sets BPDFHE apart from the other two methods and makes it the best of the three methods described above. Moreover, the generated BPDFHE images are well suited for segmentation by the Adaptive Threshold image method, which is controlled grounded on kernel fuzzy clustering, resulting for successful segmentation.

3.9 Intensification (INT) Operator, Fuzzy Type-I and Fuzzy Type-II Methods

Research [15] was conducted with the goal of protecting MRI scan information from noise without deleting essential data from input photos. Since there are many uncertainties in image acquisition and the success in image improvement varies significantly depending on the topic, the INT Operator and fuzzy types contrast enhancement method was used in this research. Many of these problems can be solved very well using INT Operator and fuzzy Types. The survey determines that the suggested strategy outperforms the conventional methods in terms of performance. MSE, RMSE and PSNR were chosen as the characteristics of the imaging system.

3.10 Contrast Guided Interpolation (CGI) Technique and Iterative Back Projection (IBP) Filtering

In a study published in 2018, Hong Zheng et al. used incline info from previous high-contrast resolution images to enhance the different components of MRI images of the brain. The CGI and IBP filters were used in the review because the new match on a MRI image is more accurate and comprehensive, with higher visual clarity and resolution than the previous study [16]. This study determines that the method used for both fake and real MRI input images is quite useful. To further enhance the properties of MRI brain images, it is recommended to reapply the IBP filters according to this algorithm.

3.11 Multistable Stochastic Resonance (MSSR)

In 2018, researchers [17] conducted a study to improve or maximize the efficiency of dynamic contrast in benign tumor detection. In the study, the multistable stochastic resonance technique was used. The results show that when applied to the Brain Web dataset created from simulated MRI data, the proposed technique outperforms the results obtained with the proposed algorithmContrast Limited AHE, DSR, Brightness Preserving Dynamic Fuzzy HE based on quartic bi-stable, Linear Minimum Mean Square Error + BPDFHE and Linear Minimum Mean Square Error + Contrast Limited AHE.

3.12 RBFNN - Radial Basis Functions Neural Network Filtering

Gao et. Alconducted a study in2016 to compare different denoising techniques for MR images of the brain and fundus images of the retina. Filtering by RBFNN's was used. The conclusions show that this technique is effective and provides better outcomes compared to the denoised wavelet technique and the subspace technique [18].

3.13 GWO (Grey Wolf Optimization) Method

Research [19] presented in 2018 to improve visual contrast and reduce noise. They used the Grey Wolf Optimization (GWO) approach. Compared to other approaches, the outcome gives excellent contrast and higher exposure. Compared to GA, CS and PSO, the convergent GWO provides better and faster parametric expansion of logarithmic

Table 1. Comparison of different Enhancement methods of MRI images

Enhancement Methods	Mean Square Error Values			PSNR Values		RMSE Values	
	Clinical datasets	BRATS	Brain Web	Clinical datasets	BRATS	Clinical datasets	BRATS
Median	203.84	–	–	25.07	–	–	–
Median + Mean + Midpoint	–	–	–	43.67	–	–	–
Median + Weiner	–	23.90	–	–	34.81	–	–
Alpha trimmed mean filter	1.944	–	–	45.299	–	–	–
AGC method	–	–	–	17.73	–	–	–
Non local means filter	0.025	–	–	18.021	–	–	–
Homomorphic	0.035	–	–	16.543	–	–	–
AHE method	–	–	–	–	21.675	–	–
AIR-AHE	–	–	–	87.37	–	–	–
BPDFHE	–	63.538	–	–	29.939	–	7.54
INT Operator	1.1226	–	–	100	–	0.0747	–
CGI + IBP	–	–	–	–	–	–	–
GWO method	–	–	1212.16	–	–	–	–
RBFNN filter	–	–	–	18.03	–	–	–

transformation. It also needs a lesser amount of time to obtain the best results and providesmore sophisticated image. Compared to other approaches, the proposed technique has the maximum PSNR values. In most cases, the proposed approach has minimum killing time, which is crucial for practical application.

In Table 1 to evaluating the performance of image improvement, the parameters MSE, RMSE, and PSNR are used. MSE measures how much the improved image differs from the original image, RMSE measures the difference between the input image and the segmented image, and PSNR measures how alike the improved image is to the given input image. This likeness influences how accurately the lastdiagnosis is made by the AI system. The smaller value of MSE, RMSE and the higher the value of PSNR, the better will be the quality of the output image [20].

4 Conclusion

Image preprocessing helps to preserve the specific information about the object under analysis in its original state by minimizing various types of noise present in the original input image and storing the patient's original image information. The results of the review show that the effectiveness of the additional filter is influenced by the preprocessing technique used to improve MRI image quality. To reach the next level and obtain more accurate information, the data or significant particulars contained in the original image were enhanced by selecting an appropriate preprocessing technique. According to this review, the best preprocessing technique for the Clinical dataset with the maximum PSNR value of 100 and the lowest RMSE value of 0.0747 was the intensification (INT) operator. The Non-Local Means filter, which has the lowest MSE of all preprocessing techniques-0.025-was most effective for the clinical dataset.The outcomes of this study can serve as a basis for developing a system to preprocess MRI brain images for future research to assist in the rapid diagnosis of brain tumors by investigating the preprocessing technique described in this survey.

5 Future Scope

In the previous comparative study of noise decrease filters like mean filter, median filter, gamma filter and fuzzy filter were presented in the form of tables. Further research may focus on RBFNN filter, MSSR Filter and integration of GWO filter.

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