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Brain MRI Image Denoising Using Spectral Total Variation Denoising

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Abstract

To diagnose the brain cancer, Magnetic Resonance Image is considered as one of the efficient technologies. For disease diagnosing, the information received from MRI images is used by the radiographer to provide the concern treatment for the patient further. However, noise is always contained in MRI images. From images, elimination of noise is very critical and important task. In prior to the proceeding to next task, it's required to be implement the pre-processing steps if in case the images are accumulated with the noise. For removing of noise, filtering algorithms are used. A major drawback in the existing denoising algorithms is that the resultant image suffers from blurring as the edges are affected in the process of filtering. This paper proposes an image denoising technique with the spectral total variation which reduces the noise in the image without blurring the edges. The existing algorithms have been implemented to compare the performance of the proposed system.

1. INTRODUCTION

In MS Word 2007, this template has been changed and saved as a format of "Word 97-2003 Document" for the PC. In order to prepare electronic versions of the technical papers, authors have been provided with most of the specifications of formatting. For three reasons, all of the standard paper components have been particularized such as: (1) ease of use while formatting the individual papers, (2) compliance to electronic requirements automatically that offer the electronic products with concurrent or later production and (3) style conformity throughout the proceedings of conference. Different kinds of type styles are provided for over the complete document such as type styles, line spacing, column widths, and margins and these are mentioned in italic type, within parentheses. Although different types of table text styles are provided, some components are not prescribed such as tables, graphics, and multi-leveled questions. The formation of these components and incorporation of the applicable criteria will have to be followed by the formatter. In the field of medicine, the Medical imaging is a crucial instrument. For generation of high quality images, Magnetic Resonance Image (MRI) is an imaging technique that can be widely utilized in medical setting for providing the effective information related to the inside of the human body [1, 2]. By using a number of corresponding precise, quick, and flexible tools of diagnosis, the clinician is presented the MRI. To measure the organ anatomy in a simple manner precisely, very potential method is to be considered as Magnetic Resonance Image. In medical image processing [3], it's very essential for obtaining correct image to make easier the observations for an application accurately. For determining the normal and abnormal types of brain, it can also be utilized.

The noises are involved in the medical images and corrupted unfortunately. In the original signal, an unwanted signal is presented i.e. noise. It is produced at any time or any form. A faulty memory can be caused a noisy image. During transmission, noise in a channel and a faulty sensor in camera is made occurred. Salt-and-pepper noise is viewed on medical images and it is a typical noise. Black or white or both pixels are occurred over the images randomly. In the images data transmissions and disturbances [4], the errors are caused the degradation. For efficient quantitative measurements, feature extraction and analysis, image with a low quality is not useful that is created a problem. From medical image, the removal of noise is a significant task and it's not easier to denoise the image. For more precise diagnosis, the image quality should be improved with the process of denoising [5, 6]. Without degrading the details of an image, the noise is reduced in homogeneous area through denoising. For a method of post processing like segmentation, restoration, pattern analysis, classification, and others [7], denoising is most widely used technique. Before being subjected to the analysis further, noise images need to perform the pre-processing phase conventionally. For removing of noise in pre-processing, the algorithm of filtering is the popular method. For enhancing the quality of an image and increasing the visibility, the algorithm of image filtering is utilized in medical imaging that assist in the proper diagnostic process [5]. To make the filtering, those techniques are used for elimination of noise and implemented the task of image segmentation on the images [8]. For removing the noise and image segmentation into various particular regions, the method of denoising based segmentation is to be utilized in the medical images.

2. Mri Medical Image Denoising Fundamental Filters

In medical image processing, a fundamental role is played in the statistical models of noise and signal. In the image processing of magnetic resonance (MR), various different applications are involved particularly that relied on a prior model of well-defined statistical data. In the literature, different model-based methods may be determined such as signal estimation and noise removal techniques as the conventional approach. In the field of MR image processing, the Denoising of MR image has considered as a main research area. In the systems of MR image processing, removing and decreasing of noise process is the core problem. The added noise in the MR original image is eliminated with the use of this technique. The MR image's quality may get defective while the processing, capturing, and storing of MR image. Still, a challenging issue is the removal of noise from the original MR images for researchers due to the noise elimination is initiated the artifacts and created the MR images' blurring. In the medical imaging specifically the Magnetic Resonance Imaging (MRI), an essential purpose has been involved as MR image de-noising [9]. On MRI images, various de-noising and improvement methods are implemented.

One of the important branches of processing of MR image is considered as De-noising. In all of the systems, the major use is determined basically that gains multidimensional or mono-dimensional signals. In the clinical diagnosis, an important role is played by the Magnetic Resonance Imaging (MRI) which helps to produce the high quality images with 2-D and 3-D of the body which is impacted by noise. In the literature, various types of de-noising methods have been introduced recently. The reduction of the noise amount is the major challenge for regulating the MR image based on the information of preservation, the edges, and the small structures that would be critical for a proper diagnosis. The identification of three essential families of MRI de-noising filter [10] can be accomplished such as methods operating in a transformed domain, defining the methods in the spatial domain, and methods using the signals' statistical properties. In order to decrease the noise amount, an average of pixels is applied for filters in the spatial domain.

Up to now, various techniques are improved for MR image de-noising and each technique has its own benefits and drawbacks. Based on the amount and type of noise available in the MR image, the technique will be implemented and will prove that it will reduce the noise. Other factors should be also considered such as computational time, performance in denoising the MR image, and computational cost.

In different domains such as Wavelet Domain, Frequency Domain, and Spatial Domain, de-noising can be exhausted. In the processing of MR image, filtering is a method that can be incorporated for different tasks such as re-sampling, interpolation, and reduction of noise. By relying on the available amount and type of noise in an image, the filter has been chosen due to the efficient removal of different kinds of noise is possible with the use of various filters.

Adaptive Wiener filter:

Adaptive Wiener Filter (AWF) is considered as frequency domain filter. According to the MR image's statistical features inside the region of filter, the behavior is changed in the adaptive Wiener filter and the maximum rectangular window is defined. The performance of adaptive filter is superior to the non-adaptive counterparts. By using the mathematical measures like variance and mean, the adaptive filters can be designed [11]. According to the computed statistics from each pixel's local neighborhood, a pixel-wise adaptive Wiener technique is used in the adaptive Wiener filter. By making use of filtering of pixel-wise adaptive Wiener, the MR image is filtered out by its function. To compute the standard deviation and mean of the local MR image, neighborhoods size M-by-N is used.

Non-linear filters:

To restrict the linear filter's defects, numerous kinds of non-linear filters have been improved such as max filter, min filter, adaptive median filter, and median filter. The better performance could be reached by non-linear filters when compared to the linear filters [12]. However, the spatial domain filters are considered as the non-linear filters. The adaptive median filter and the median filter are demonstrated in the below-mentioned section in detail.

Median Filter:

Median filter is come under the categorization of spatial domain filters and is also most common used nonlinear filter. Based on the MR images' smoothing, the noise is removed by the filter. The variation of intensity between one and other pixels of an MR image is lowered by this filter. The replacement of MR image's pixel value is done with the median value in the algorithm of median filter [13]. In two step procedure, the value of median is estimated. The ascending order of all pixel values is arranged in the first step. The pixel values are calculated that being replaced with the middle pixel value in the second step. By averaging the two middle pixel values, the pixel is replaced by the algorithm when considering the MR image's neighboring pixel and even no pixels also. Owing to the capability of median filters to achieve the efficient reduction of noise with not much as of blurring for different types of noise, the researchers are utilized the median filters most commonly. For MR image processing, median filters are widely utilized as well as in the time series processing and signal processing. By comparing with the linear filters, the median filter has an essential benefit is that it can eliminate the values of input noise impact with the extreme large magnitudes.

Adaptive Median Filtering:

Instead of using the traditional median filtering, the Adaptive Median Filtering (AMF) [14] has been implemented as an advanced de-noising technique. For determination of MR image's pixels that is corrupted with noise, the spatial processing has been executed using adaptive median filter. With the comparison of every pixel in the MR image to its neighbour pixels surrounded, the pixels are classified as noise by the Adaptive Median Filter. The neighbourhood window's size is adjustable as well as the threshold to compare the values. From a majority of the neighbours, a pixel is different and is no alignment with those pixels structurally to which it is same as labelled as noisy pixel. In the neighbourhood, the pixels' median value is exchanged these noisy pixels that have approved the test of noise labelling. Based on the operation, the neighbourhood window's size is changed by the adaptive median filter. In classic median filter, the constant value is included the neighbourhood window through the operation. If the higher value is included in the impulse noise density, the standard median filter doesn't process well whereas the adaptive median filter can deal with these noise better. The details of MR image is preserved in the adaptive median filter and those are involved as smooth non-impulsive noise and edges. However, it doesn't achieve with the use of standard median filter.

Denoising images is therefore an important issue. The human eye knows very well how to denoise images representing natural scenes, in the sense that a noise of reasonable intensity does not prevent not the visual system to understand a scene, down to a fairly fine degree of detail. Doctors coaches also manage to ignore noise when they analyze medical images. However, automating such a task is not easy, because it involves reconstructing a information lost during the sound effects process, on extremely varied data.

3. Proposed Spectral Total Variation Denoising

As most of the images could have involved the same noise image almost, the recovery from noise is not a simple task if in case an image has corrupted with the noise. To limit the set of plausible solutions, one can consider some type of regularity criterion. For that, a regularity measurement is considered i.e. Total Variation (TV) which has shown efficiency for the problems of image reconstruction. Due to the feature of allowing discontinuities along the edges which are located on regular enough curves, it has the capability of adapting to piecewise constant images (cartoon images). Additionally, it has a good geometrical explanation in terms of level lines' cumulated length.

Let's say, an image is denoted as v, consider an assumption of a noisy version of an original image u, and corrupted the image with an additive white Gaussian noise ε, i.e.,

$$v = u + \varepsilon \qquad (1)$$

where u, ε and v are gray level images that is defined with some measurable subset Ω of R_2 . Here, make an assumption of v in L_2 (Ω). By assuming that the variance σ 2 of the noise ε is known, the main goal is to receive u back from v.The empirical variance of the noise to be close to σ^2, and the original image u is lied within the region of L_2 distance σ from the datum v can be expected when the images have included large dimension.

RudinOsher and Fatemi (Chambolle, 2004) has been introduced the first denoising method that seeks an image ***u*** of energy:

$$E_{ROF}(u) = TV_1(u) + \frac{\|f-u\|_X^2}{2\lambda} \qquad (2)$$

with: ***f*** the starting image in

$$X = \mathbb{R}^{N\times M} \qquad (3)$$

u the projected image.

The minimization criterion brings into play a term of attachment to the data and the term of total variation:

$$TV_1(u) = \sum \|\nabla u\|_{\mathbb{R}^2} \quad (4)$$

Which can be seen as a measure of the total length of the contours in an image. This method gives rise to the aforementioned staircasing effects, which we illustrate in the Results section.

The extension of energy to order 2, in discrete, is done very easily by replacing the gradient's norm by the norm of the Hessian (differential of order 2). We thus obtain the total variation of order 2:

$$TV_2(u) = \sum \|\mathrm{H}(u)\|_{\mathbb{R}^2} \quad (5)$$

Then it suffices to introduce it into the expression of energy in place of the total variation and we obtain:

$$E_{ROF2}(u) = TV_2(u) + \frac{\|f-u\|_X^2}{2\lambda} \quad (6)$$

By going to order 2, the constant zones do indeed disappear, but there is a blurring effect.

The term of total variation is referred to the clean image's statistical prior distribution. The total variation with three-dimensional anisotropic is described as follows:

$$DTV_2(u) = \|TV_2(u)\| = \sum_i (\beta_x |[D_x f]_i| + \beta_y |[D_y f]_i| + \beta_y |[D_\lambda f]_i|) \quad (7)$$

Where Dλ, Dx, and Dy are representing the matrices that describe the first-order forward finite-difference operation along the wavelength, horizontal, and vertical directions respectively. Further the operator D is defined as

$$D = \begin{bmatrix} \beta_x D_x \\ \beta_y D_y \\ \beta_\lambda D_\lambda \end{bmatrix} \quad (8)$$

where Dx, Dy, and Dλ are represented the relative emphasis which are computed with the use of parameters βx, βy, and βλ, respectively. The term $\|TV_2(u)\|$ in equation 6 can be rewritten as $DTV_2(u)$, thus producing

$$E_{ROF2}(u) = DTV_2(u) + \frac{\|f-u\|_X^2}{2\lambda} \quad (9)$$

The following section presents the experimental analysis carried out using the proposed method.

4. Results

This section presents the experiments conducted for the analysis of the proposed method. The figures 1 to 9 show the input images, noisy images and denoised output obtained in the experiment.

Figures 1, 2 and 3 represent the input image, noisy image and the denoised image respectively. The PSNR of the resultant image is 32.2534.

Figures 4, 5 and 6 represent the input image, noisy image and the denoised image respectively. The PSNR of the resultant image is 30.6477.

Figures 7, 8 and 9 represent the input image, noisy image and the denoised image respectively. The PSNR of the resultant image is 32.7866.

By comparing with the existing filters, the proposed method is evaluated. The PSNR values have been presented in table 1.

The proposed method performed better when compared to the existing techniques.

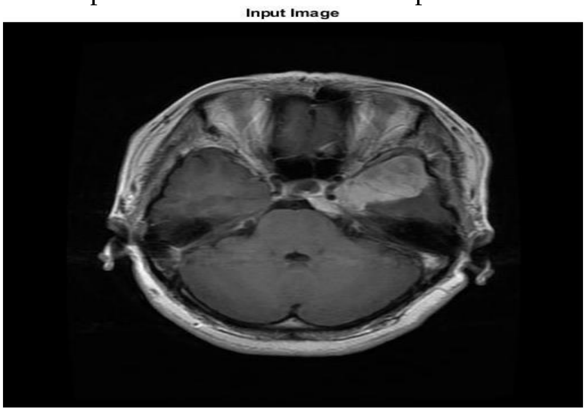


Figure 1. Input MRI image 1

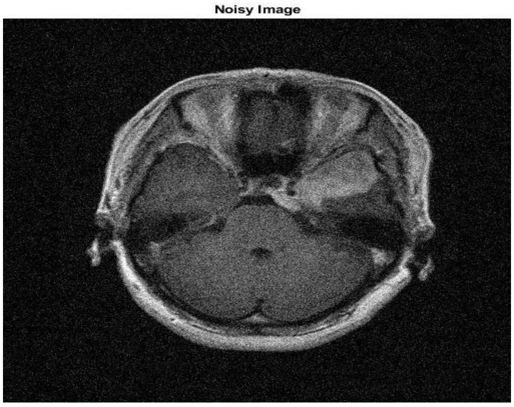


Figure 2: Noisy MRI image 1

Figure 3: Denoised MRI image 1

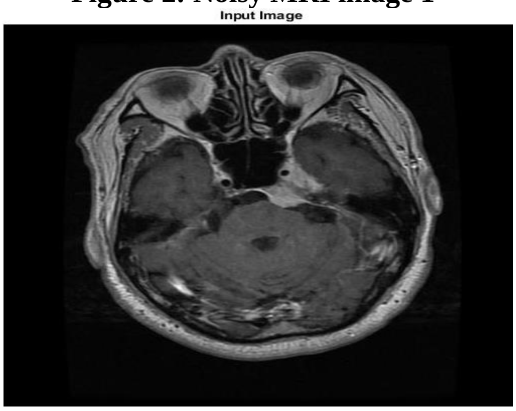


Figure 4: Input MRI image 2

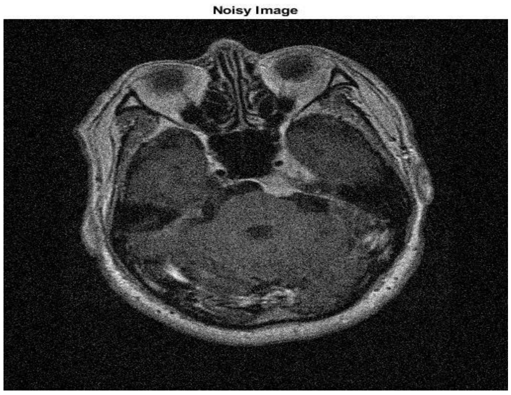


Figure 5: Noisy MRI image 2

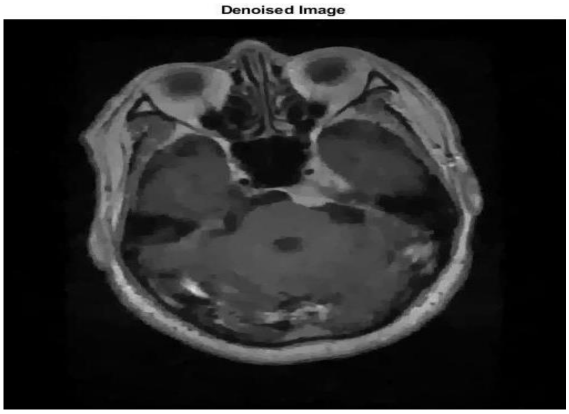
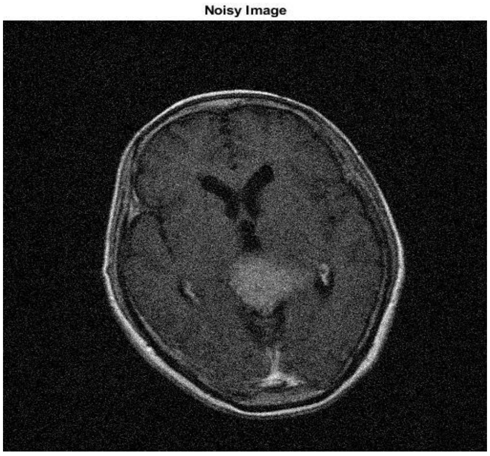


Fig 6: Denoised MRI image 2



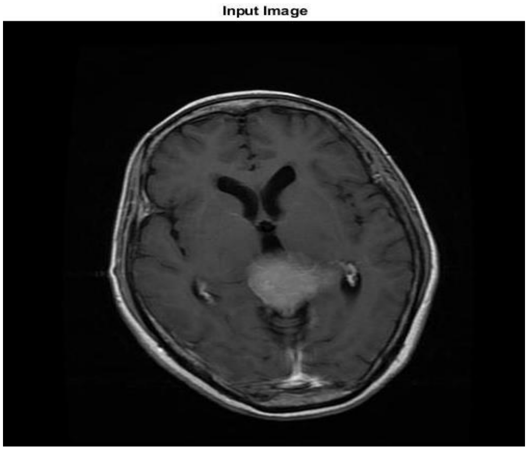


Fig 7: Input MRI image 3 **Fig 8: Noisy MRI image 3**

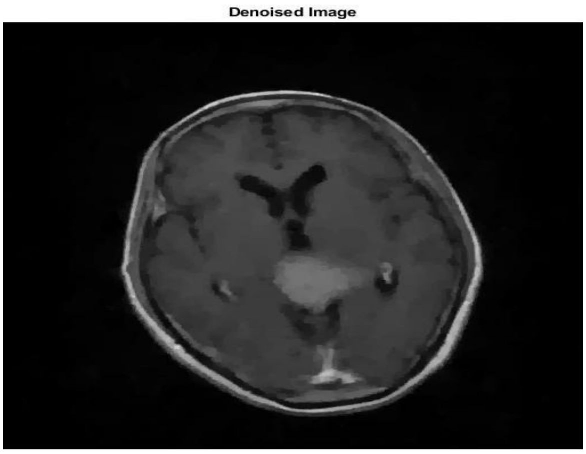


Fig 9: Denoised MRI image 3

Table 1: Comparative results

	Media Filter	Adaptive Median Filter	Adaptive wiener filter	Proposed Method
Image 1	24.23	26.42	28.95	32.25
Image 2	22.54	24.75	27.65	30.65
Image 3	25.95	26.24	28.79	32.78

5. CONCLUSION

A research challenge is imposed by the increasing number of patient data in medical images for providing the scientific treatment through diagnosing, identifying, and predicting the diseases. Pre-processing and de-noising the image is a significant step in the automatic detection of brain tumor. This research proposed a Spectral Total Variation algorithm which performs de-noising on the image along with preserving the edges. The proposed algorithm outperformed the existing denoising algorithms.

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