Multiple Sclerosis Lesions Identification Technique
Using MR Images

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Abstract—In this paper a new effective diagnosis method is introduced to identify the Multiple Sclerosis (MS) lesions in Brain tissues. The method involves the implementation a number of digital image processing techniques. First, removing the skull bones (i.e. extracting the brain tissues) by converting the MRI image into a binary format (utilizing threshold value), determining a seed point at the center of the binary image (i.e. representing the middle of coordinates), then proceed from the seed point radially and stop at the borders of the brain material (zero) values. Isolating the brain substance is performed by multiplying the retained binary patches (having values one) by the original image. Image edge detection (based on convolution with Laplacian-Gaussian operator) is then performed to identify the single pixel and closed borders of the brain materials (including the lesion areas). The lesions areas can then identified by determining a seed point for each unexpected small contour areas within brain tissue, and moving radially from these seeds (outward) to the delineated border of each lesion.

Keywords-- lesions identification, MR images, skull bones stripping, extracting brain tissue, brain edge detection

I. INTRODUCTION

Determining the pathological cases of the Multiple Sclerosis (MS) was the objective of the too many published researches during the ten past. The pathological evaluation criterion was the preferred diagnosis for this disease, but the many existing constraints limited this diagnosis; e.g. the availability of tissue biopsy and autopsy. For those reasons, the Magnetic Resonance Imaging (MRI) has gained a leading role in the evaluation of MS because it allows physicians to get a picture before the death of the central nervous system [1]. Consequently, a number of correlative pathological and MRI studies have developed to help define in vivo the pathological substrates of MS in focal lesions and normal-appearing white matter, not only in the brain, but also in the spinal cord [2]. Normally, brain tissues are classified by three ways; i.e. White Matter(WM),Gray Matter(GM),and Cerebrospinal Fluid(CSF). MS is a chronic autoimmune disorder affecting movement, sensation, and bodily functions. It is caused by destruction of the myelin insulation covering nerve fibers (neurons) in the central nervous system (brain and spinal cord) [3]. MRI has become an essential tool in the diagnosis of MS since it is able to demonstrate dissemination in space and time of demyelinating lesions and to rule out alternative diagnosis, especially applicable to the T2-weighted MRI images[4].

II. MAGNETIC RESONANCE IMAGING (MRI) TECHNIQUES

The MRI of the brain is a safe and painless test that uses a magnetic field and radio waves to produce detailed images of the brain and the brain stem. It provides detailed information about brain tumor anatomy, cellular structure and vascular supply, making it an important tool for the effective diagnosis, treatment and monitoring of the disease. It is used for many purposes; e.g. identifying tumors, bleeding, injury, blood vessel or infection. The MRI provide more information than other currently used scans; e.g. X-ray, Ultrasound, or CT. Contrast material may be used during MRI to recognize affected brain tissues more clearly. It is thus useful in segmenting the WM, GM and CSF, and to defining the lesions present [5]. Modern brain imaging techniques like MRI are becoming indispensable to researchers studying MS and its effects on the brain. Different scan types of MRI provide different information, for examples:

1. **T1-weighted** brain MRI scan, enhanced with gadolinium (injected intravenously to further enhance scan sensitivity), supplies information about current disease activity by highlighting areas of active inflammation. Because gadolinium is a large molecule, it normally cannot pass through the blood-brain barrier. However, when there is active inflammation, the blood brain barrier is disrupted and gadolinium can enter and highlight the inflamed areas, and thus appear as active lesions. Furthermore, T1-weighted images also show dark areas that may be thought to indicate areas of permanent nerve damage.

2. **T2-weighted** images provide information about disease problem or lesion load (i.e. the total amount of lesion area, both old and new).

3. **FLAIR** (fluid attenuated inversion recovery) images are used to better identify brain lesions associated with MS.

4. **Spinal cord imaging** can identify pathology in the cord. It can also help establish the diagnosis of MS by demonstrating that damage has occurred in different parts of the central nervous system at different points in time.
Samples of multiple sclerosis MR images are shown in Fig. 1.

Axial T1- MRI with MS with several white matter lesions
Axial T2- MRI with MS demonstrates several white matter plaques in white matter
T2 FLAIR of bright spots represent lesions marked by black arrows
Sagittal proton density– MRI with MS with white matter lesions.

Fig. 1 shows samples of weighted MRI of MS patients [6].

In order to make a diagnosis of MS, the physician must:
1. Find evidence of damage in at least two separate areas of the central nervous system (CNS), which includes the brain, spinal cord and optic nerves AND
2. Find evidence that the damage occurred at least one month apart AND
3. Rule out all other possible diagnoses

III. STRIPPING MRI OF THE SKULL BONES
The stripping process of MR images of the skull bones and retaining only the brain tissues pass through the following stages:

A. Image Binarization Process
In this the MR image is converted into binary format using a suitable threshold value, as given in Eq.(1) below;

\[
\text{Bin}(x, y) = \begin{cases} 
1 & \text{if } \text{MRI}(x, y) \geq \text{Th} \\
0 & \text{Otherwise}
\end{cases}
\]  

(1)

Where: \text{Bin}(x, y) represents the output binary formatted image of the input \text{MRI}(x, y), \text{Th} is the decided suitable threshold value. We have found that the best threshold value that is done very well with most images was \text{Th}=35.

Fig. 2 illustrates samples of different weighted brains MRIs and their binary versions.

B. Extracting the Brain Tissues by Seeded Region Growing Method
After converting the MRI processed image to the binary format, and to proceed forward in the process of extracting the brain tissue. We must be sure that the candidate seed point lies within the binary region of the brain’s tissue. In this work, the coordinates of the seed point is selected (automatically), represent the mid-axes of the processed image; i.e.

\[
X_{\text{mid}} = \frac{\text{Number of image columns}}{2}; \quad \text{and} \\
Y_{\text{mid}} = \frac{\text{Number of image rows}}{2}
\]  

(2)
As the coordinates of the seed point is specified, we move toward the image frame in a radial-circular shape, stopping only when we encounter by a pixel of zero value. The radial-circular shape of the seed growing process is illustrated in Fig. 3.

![Fig. 3](image1)

Original MR image  The binary image  Extracted region using the radial-circular seed growing

Fig. 3 Illustrates the process of extracting the brain tissues by using the seed growing method.

The true image of the extracted tissues of the brain can now be identified, representing the zero pixels' values of the radial-circular seed growing image. Fig. 4 shows the extracted tissues of the test MRI images.

![Fig. 4](image2)

Extracted tissue of sample-1  Extracted tissue of sample-2  Extracted tissue of sample-3  Extracted tissue of sample-4

Fig. 4. Illustrate the truly extracted tissues of the processed images.

As is obvious, the process of the extraction was not successful with the samples 3&4. The reasons were; the MRI of sample-3 involves many cavities while sample-4 was contaminated by large amount of noise. To overcome these problems, both those samples have subjected to filtration process (using median filter) with large-sized window (i.e. 15x15 pixels). The results are shown in Fig. 5.

![Fig. 5](image3)

Sample-3: median filtered; \( Th=2 \)  Sample-4: median filtered; \( Th=35 \)

Fig. 5 Improves extraction of images subjected to median filter, and different binarization threshold.

IV. DETECTING BOUNDARIES OF THE BRAIN TISSUE'S COMPONENTS

Automatic image analysis depends greatly on image segmentation into regions corresponding to individual objects. Assuming that these regions have some homogeneous characteristics; e.g. luminance, color, texture, etc. One segmentation technique is to detect sharp transitions (called edges), and then connecting these edges to outline the desired boundaries. Till now, a large number of edge detection techniques have been reported in the literature, for instance see [7]. Some of these techniques have found either unreliable for detecting boundaries in noisy images or too specific to cover a broad class of problems [8]. The edge detection to be considered in this paper combines many good points the edge detection methods on the basis of its quantitative and qualitative performance. The elegance in the selected edge detector lies in its ability to produce thin edge (single-pixel) and connected edge segments.

The Gaussian filter is one of the most widely smoothing filter used in image processing; it is extremely useful to reduce the impact of noise, which often appear as false edges in many edge detection methods. Mathematically, the 2D Gaussian function is defined as;

\[
G_\sigma = \frac{1}{2\pi\sigma^2} e^{-\frac{(x^2+y^2)}{2\sigma^2}} \tag{3}
\]
Where \( \sigma \) is the standard deviation, and \((x, y)\) are the Cartesian coordinates of the image pixels. In fact, applying Gaussian filters of different \( \sigma \) to an image, different levels of smoothing will be achieved and, consequently, different edges are detected. On the contrary of the Gaussian operator, the Laplacian is a second order differential operator given by the divergence of the gradient of a function on Euclidean space. It is usually denoted by the symbols \( \nabla \nabla = \nabla^2 \). To detect the edges in an image Marr and Hildreth [9] proposed to detect the zero-crossings points of the second derivatives. This is achieved by convolving the image function with the Laplacian of Gaussian (LOG) function, and looking for the zero-crossing to represent the image edge points. Mathematically, the LOG function is presented by:

\[
\nabla^2 G_\sigma = -\frac{1}{\pi \sigma^4} \left(1 - \frac{x^2 + y^2}{2\sigma^2}\right)e^{-\frac{(x^2+y^2)}{2\sigma^2}}
\]

The LOG function edge detector with different \( \sigma \)-values are performed on the brain's tissues extracted images, the results are shown in Fig.6.

<table>
<thead>
<tr>
<th>( \sigma ) value</th>
<th>Image Sample-1</th>
<th>Image Sample-2</th>
<th>Image Sample-3</th>
<th>Image Sample-4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td><img src="image1.png" alt="Image Sample-1" /></td>
<td><img src="image2.png" alt="Image Sample-2" /></td>
<td><img src="image3.png" alt="Image Sample-3" /></td>
<td><img src="image4.png" alt="Image Sample-4" /></td>
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<tr>
<td>3</td>
<td><img src="image1.png" alt="Image Sample-1" /></td>
<td><img src="image2.png" alt="Image Sample-2" /></td>
<td><img src="image3.png" alt="Image Sample-3" /></td>
<td><img src="image4.png" alt="Image Sample-4" /></td>
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<tr>
<td>5</td>
<td><img src="image1.png" alt="Image Sample-1" /></td>
<td><img src="image2.png" alt="Image Sample-2" /></td>
<td><img src="image3.png" alt="Image Sample-3" /></td>
<td><img src="image4.png" alt="Image Sample-4" /></td>
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Fig.6. Marr-Hildreth edge images by different values of Gaussian standard deviations.

V. MULTIPLE SCLEROSIS LESIONS IDENTIFICATION PROCESS

Multiple sclerosis (MS) is an inflammatory demyelinating disease that affects the CNS by causing focal lesions in white and grey matter and diffuses and unevenly distributed changes in normal-appearing tissue. Pathological studies have helped to define the heterogeneous pathological substrates of this disorder, with the ultimate goal of identifying processes that might be targeted by therapeutic interventions. Although pathological assessment is regarded as the gold standard for such research, it is usually done at late stages of the disease (autopsies) or in selected and partly atypical early cases (biopsies). Additionally, pathological assessment usually provides only one snapshot in time, and therefore does not allow observation of the evolution of pathological changes over time. Because MRI is particularly useful in detecting CNS demyelination, it is a powerful tool in helping to establish the diagnosis of MS. However, approximately 5% of people with clinically-definite MS do not initially show lesions on MRI at the time of diagnosis. Since many lesions seen on MRI may be in so-called "silent" areas of the brain that don’t produce symptoms, it is not always possible to make a specific correlation between what is seen on the MRI scan and the person's clinical signs and symptoms. However, once a diagnosis of MS has been clearly established, there is no reason why an MS patient should have further diagnostic MRI scans. Subsequent scans, however, are useful in tracking the progress of the disease and making treatment decisions. In our research, it has been assumed that the bright or dark spots in the brain white matter and specified by closed contours, utilizing the Marr and Hildreth "LOG" edge detector, representing MS lesions in an infected patient's brain. A seed point in each suspected contour was chosen (manually), the contoured region then delineated by red line boundary, as illustrated in Fig.7. It is remain to mention that; the preferable standard deviation "\( \sigma \)" in performing the LOG edge detection was equal to 3.
VI. TEXTURE ANALYSIS IN MULTIPLE SCLEROSIS

As mentioned before, the Multiple Sclerosis disease is characterized by heterogeneous pathology that varies from patient to another. Accurate identification of pathological changes may simplify the understanding of the disease pathogenesis and progression and help in identifying a better therapy for MS patients. Utilizing texture analysis, the relationships between image pixels can be evaluated, and new patterns can be produced which are beyond the ability of visual perception. Different texture analysis methods for analyzing MS diseases have been proposed in the literature, for instance see [10]. In this research, the co-occurrence matrices method which was introduced by Haralick, et al [11] will be used to support the results that have been obtained using the above mentioned method of edges and closed contours. Haralick et al have proposed a variety of measures that can be used to extract useful information of textural image regions. Only three of these measures will be used in this study; i.e.

\[
\text{Dissimilarity} = \sum_{i,j} |i - j| p(i, j) \tag{5}
\]

\[
\text{Entropy} = -\sum_{i,j} p(i, j) \log(p(i, j)) \tag{8}
\]

\[
\text{Homogeneity} = \sum_{i,j} \frac{1}{1 - (i - j)^2} p(i, j) \tag{9}
\]

Where \( p(i, j) \) is the normalized \((i, j)\)th element of the co-occurrence matrix, given by; [8]
Where: for angles quantized to 45°:

\[ N_\theta = \begin{cases} 
2 N_r (N_y - 1) & \text{for } r = 1 \text{ and } \theta = 0^\circ; \\
2(N_r - 1)(N_y - 1) & \text{for } r = 1 \text{ and } \theta = 45^\circ \text{ and } 135^\circ; \\
2 N_r (N_y - 1) & \text{for } r = 1 \text{ and } \theta = 90^\circ 
\end{cases} \]

Where: "r" is the radial separate distance between tested pixels.

Fig. 8 shows examples of co-occurrence images counted by Eqs.(5 to 9). To illustrate the scratches and lesions in the brain tissue, the tissue area was enlarged and subjected to what has been conducted in the colorful image of Fig. 8, as illustrated in Fig. 9.
VII. CONCLUSIONS

In this paper, several special techniques of digital image processing topic have been applied to detect the scratches and lesions affecting the brain tissue of multiple sclerosis patient, using different weighted MR images. Starting from the stripping process of the brain tissue from the skull’s bones, passing through the specifying process of the edges and borders of the brain's meanders and malformations, and down to the delineation of the expected lesions in the myelination brain's areas. Although the diagnosis of pathological cases of patients with multiple sclerosis is currently based on clinical diagnosis, but the development of new methods and techniques using radiography of nervous (specially the use of MRIs) started approaching the identification of structural abnormalities in the brains of patients who suffer from this disease. The results in our current research showed that the T1 and T2 weighted slices of MRIs are the best for the completion of the diagnostic process. It remains to point out that the proposed technique in this paper could be developed to monitor the possible complications in cases of patients by taking extra MR images in certain time periods (e.g. every 6-12 months).

REFERENCES