LOCALIZING MULTIPLE SCLEROSIS LESIONS FROM T2W MRI BY UTILIZING IMAGE HISTOGRAM FEATURES

BAYDAA TAHAl AL-HAMADANI
Computer Science Dept., Zarqa Universirt, Jordan. P.O.Box 132222, Zarqa, Jordan, 13132
Email: bhamadani@zu.edu.jo

ABSTRACT

Multiple Sclerosis (MS) is one of the most frequent causes of permanent disability in young adults by damaging the central nervous system through the demyelinating process. As most of the demyelinating diseases, MS is asymptomatic. Hence, to diagnose and monitor the progress of MS patients, brain Magnetic Resonance Imaging (MRI) is used in order to localize MS lesions. According to McDonald’s criteria, white lesions, appeared in T2W MRIs, in callosum and periventricular areas are typical.

In this context, this paper proposed a fast localization and segmentation algorithms to localize MS lesions based on histogram features besides morphological features such as place, area, and intensity of the lesions appeared in the monitored places. The segmentation algorithm supplies the radiologist with the area of the detected lesions which considered to be valuable information in the process of monitoring the progress of the disease.

The evaluation procedures were carried out using two different clinical databases with 664 brain MR images. The results showed that the proposed technique achieved competitive sensitivity, specificity, predictive, and accuracy with 90.4, 95.6, 96.4, and 92.1 respectively. The average overall execution time with 12.3ms is considered to be fast compared with other proposals.

Keywords: Multiple Sclerosis, Histogram Equalization, Morphological Features, Magnetic Resonance Imaging, Texture Features, Localizing Lesions, Segmenting Lesions.

1. INTRODUCTION

Multiple Sclerosis (MS) is the most autoimmune demyelinating disease which causes serious damage to the central nervous system [1]. During the past few years, this disease increased dramatically causing serious symptoms such as optic neuritis and sensory problems, and it might cause permanent disability in patients with an average age of 29.2 years [2, 3]. Thus, scientists in different fields such as clinical, physical and technological scientists are trying their effort in order to diagnose and control the disease, and monitor the patient’s treatment.

The progression of MS cannot be detected through particularly known symptoms or specific laboratory tests. For this reason, Magnetic Resonance Imaging (MRI) become the significant way, since 2001, in the process of managing patients with MS [4]. According to McDonald’s criteria for MS [5] and its revisions [6-8], the process of diagnosing MS cannot be done by clinical symptoms only, it should be accompanied by brain and spinal cord MR images where white lesions appear in the Callosum, periventricular, and juxtacortical of the brain. These lesions are disseminated in time, where new lesions appeared, and space, where multiple lesions appeared. T2-weighted (T2W) MRI becomes a standard way of the diagnosing procedure since brain and spinal cord lesions appear clearly.

The periventricular area is the brain tissue that lines the outside of the lateral ventricles, which are a pair of C-shaped reservoirs filled with cerebrospinal fluid located near the center of the brain[9]. While Corpus Callosum lies beneath the cortex at the longitudinal fissure and it can be divided into four areas: Rostrum,Genu, Body, and Splenium [10]. According to McDonald’s criteria for detecting MS, white matters in these two areas are typical to appear beside their appearance in the spinal cord. Figure 1 shows two MR images. The one on the left is for a healthy person, and the one on the right is the same image where the periventricular and corpus callosum areas are shaded.

4547
Detecting and segmenting MS lesions manually by a physician is an effort, time, and money consuming process. Moreover, it is not easy to segment MS lesions from between other lesions and matters and normal brain tissue. Thus there is a discernible need for automatic detection and segmenting MS lesions. This epidemiological disease attracts the attention of several researchers, and their researches were located into two main categories, which are either to understand the nature of the disease and how to diagnose and deal with it in one group and to detect and segment MS lesions in the another group automatically. Researches of the first group can be categorized being either to discuss MS nature, symptoms, ways of diagnosing, prevalence rate around the world, and treatment [2, 5, 11-15]; while other researches aimed to spot the light on the importance and techniques of using MRI in diagnosing and monitoring the progress of MS [4, 16-18]. Whilst in the second group, several techniques were proposed to localize and segment MS lesions beside several reviews that described and evaluated the performance of these techniques [19-23]. These researches can be divided into two main categories, either supervised or unsupervised techniques.

Supervised techniques are supported by supervised algorithm such as spatially varying statistical classification (SVC), as in [24, 25], which employed a K-Nearest Neighbor (k-NN) classification scheme based on a template registration process to extract features from both normal MRI and MS patient MRI. While [26, 27] used multi-channel and context-rich random decision forest classifier by distinguishing the symmetric features of MS lesions and the mid-sagittal of the brain. In their works, [23] proposed OASIS to be an automated statistical method to estimate the presence of lesions depending on depending on voxel-level probabilities. Other methods depend on a variety of techniques such as [28] which depend on comparing images examples from Atlas to match patches using sparse dictionary; and [29, 30] that used multi-output decision trees to averaging multi-layers images; [31] which deployed SVM with longitudinal lesion segmentation.

On the other side, most proposed techniques were unsupervised that based on statistical and morphological features to outline MS lesions. One of the early proposed methods were [32] who depend on the tissue intensity distribution parameters to distinguish between MS lesions and normal brain tissue. In 2003, [33, 34] utilized a support vector machine (SVM) classifier in order to normalize tissue intensities. Later, [35] used multi-sequence segmentation and Trimmed

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Figure 1: MR T2W images. (a) healthy brain image, (b) Periventricular and corpus Callosum approximate areas (dashed).
Likelihood Estimator (TLE) to outline MS lesions depending on the prior information. The same technique had been improved later by, by [36] in the way of combining it with a Hidden Markov Chain (HMC), and further improvement had been done later by [37, 38] in the way of combining it with Mean Shift to exclude the regions which are outliers. Later [39] proposed a new segmentation approach based on the morphological features extracted by using the gray-level co-occurrence matrix (GLCM) and the gray-level run length matrix (GLRLM).

In this paper, we propose a new localization and segmentation approach based on comparing the MS patient’s MRI with a template image for a healthy person to highlight outlier area after extracting specific texture and morphological features to distinguish these areas from normal brain tissue based on the histogram equalization technique.

2. MATERIAL

Two MRI datasets were used in the evaluation phase of the proposed technique. These datasets were varying to cover all four types of MS which are secondary progressive, primary progressive, relapsing-remitting, and isolated clinical syndrome. The detailed description of the dataset are listed in the following subsections:

a. eHealth Laboratory dataset[40-43]: which is published for free by the Department of Computer Science in the University of Cyprus. It contains 38 T2W MRI obtained by a turbo spin echo pulse sequence with echo spacing of 10.8 ms, echo timing of 100 ms, and repetition timing of 4408 ms.

b. MICCAI[44]: which is published for free by the Neuroimaging Informatics Tools and Resources Clearinghouse (NITRC) and the MRIs were gathered at the University of North Carolina and Children’s Hospital Boston. It contains 45 T2W MRI with 0.5 as slices thickness. The T2 weighted images were registered to its corresponding T1, which are already registered to the standard MNI Atlas format [45]. More details about the used databases are listed in Table 1.

Table 1: Details of the databases used for the evaluation purpose.

<table>
<thead>
<tr>
<th>Database</th>
<th>#patients</th>
<th>Age (Mean ±SDV)</th>
<th>Modalities</th>
<th># Time points</th>
</tr>
</thead>
<tbody>
<tr>
<td>eHealth</td>
<td>38</td>
<td>29.9 ±10.4</td>
<td>T1W, T2W, PDW</td>
<td>4.5±0.5</td>
</tr>
<tr>
<td>MICCAI</td>
<td>45</td>
<td>NA</td>
<td>T1W, T2W, Flair</td>
<td>1</td>
</tr>
</tbody>
</table>

Figure 2: Schematic of the proposed MS lesion localization steps.
3. METHODOLOGY

The main purpose of MS Lesions Localization (MSLL) is to localize MS lesions that are located in Callosum and Periventricular areas in the brain. According to McDonalds criteria, besides spinal cord lesions, white lesions in these two areas are compulsory to diagnose MS, while other white matters that appeared in other parts could be caused by other diseases rather than MS [46]. The proposed technique has the ability to assist physicians in improving the process of interpreting medical images to be more accurate, fast, and efficient. Besides, MSLL supply the physician with useful information, such as the location, number, and size of the lesion(s) to be used for comparing MR images. As illustrated in Figure 2, the proposed MSLL consists of several stages: preprocessing, histogram equalization, feature extraction, and segmentation.

3.1 Preprocessing

The input to this stage is an MR T2W image and an image mask which is generated automatically for each database. The dimensions and formats of each used databases are different due to the differences in the scanner devices used, this reason behind using an image mask as another input for the preprocessing stage. As shown in Figure 3 (a), the MR images contain distracting background details which can affect the results of MSLL since it depends on the differences in the image histogram of a healthy person and a patient with lesions.
As in Eq. (1), removing unwanted background is done by multiplying the MR original image (Figure 3 (a)) by the generated mask (Figure 3 (b)) to produce the new MRI (Figure 3 (c)).

\[ Q(i, j) = \text{MRI}(i, j) \times M(i, j) \]  
…………….. (1)

As a second step of the preprocessing stage, a 3X3 Gaussian filter is applied to reduce false positive ratio, minimize noise effects, and smooth the image. In Eq. (2), \( f_1(x, y) \) is the Gaussian filter which applied onto \( Q(i, j) \), where \( \sigma \) represents the standard variation.

\[ f_1(x, y) = \frac{1}{2\pi\sigma^2} e^{-\frac{x^2+y^2}{2\sigma^2}} \]  
…………………(2)

The resultant image is shown in Figure 4 (b), and the applied filter is visualized in Figure 4 (a) with \( \sigma = 0.7 \). The result of applying Gaussian filter makes the required details become blur. To enhance the image and increase the contrast between background and other matters in the image, Eq. (3) is applied and the resultant image is shown in Figure 4 (c). \( T_1 \) and \( T_2 \) are two selected threshold values which are chosen to highlight the required lesions.

\[ Q(i, j) = \begin{cases} 1 & \text{if } T_1 \leq Q(i, j) \leq T_2 \\ Q(i, j), & \text{otherwise} \end{cases} \]  
……………(3)

3.2 Histogram Equalization

The process of histogram equalization had been used in several previous types of research in order to reduce the differences between images that were taken using different scanners [47-50]. This method can reduce the variation in white matter intensities (MS lesion in our case) from 7.5.
Furthermore, the histogram of a healthy

Figure 6: Sample Results Of The Histogram Equalization Stage. (A) Applying Gaussian Filter On The Masked Image, (B) Results Of Contrast Enhancement On The Filtered Image, And (C) Applying Histogram Equalization.