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An effective method for computerized prediction and segmentation of multiple sclerosis lesions in brain MRI

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ABSTRACT

Background and objectives: Multiple sclerosis is one of the major diseases and the progressive MS lesion formation often leads to cognitive decline and physical disability. A quick and perfect method for estimating the number and size of MS lesions in the brain is very important in estimating the progress of the disease and effectiveness of treatments. But, the accurate identification, characterization and quantification of MS lesions in brain magnetic resonance imaging (MRI) is extremely difficult due to the frequent change in location, size, morphology variation, intensity similarity with normal brain tissues, and inter-subject anatomical variation of brain images.

Methods: This paper presents a method where adaptive background generation and binarization using global threshold are the key steps for MS lesions detection and segmentation. After performing three phase level set, we add third phase segmented region with contour of brain to connect the normal tissues near the boundary. Then remove all lesions except maximum connected area and corpus callosum of the brain to generate adaptive background. The binarization method is used to select threshold based on entropy and standard deviation preceded by non-gamut image enhancement. The background image is then subtracted from binarized image to find out segmented MS lesions.

Results: The step of subtraction of background from binarized image does not generate spurious lesions. Binarization steps correctly identify the MS lesions and reduce over or under segmentation. The average Kappa index is 94.88%, Jacard index is 90.43%, correct detection ration is 92.60284%, false detection ratio is 2.55% and relative area error is 5.97% for proposed method. Existing recent methods does not have such accuracy and low value of error rate both mathematically as well as visually due to many spurious lesions generation and over segmentation problems.

Conclusions: Proposed method accurately identifies the size and number of lesions as well as location of lesions detection as a radiologist performs. The adaptability of the proposed method creates a number of potential opportunities for use in clinical practice for the detection of MS lesions in MRI. Proposed method gives an improved accuracy and low error compare to existing recent methods.

1. Introduction

Multiple sclerosis (MS) is a central nervous system (CNS) disease that damages to the insulating myelin sheaths around the axons in the brain. MS causes the immune system to attack these nerve fibers. The rate of progress of MS varies from person to person and can have periodic remission and relapse. The healthy brain contains white matter (WM), gray matter (GM), and cerebrospinal fluid (CSF) [1–2]. There are three main types of segmentation approaches: manual, semi-automatic, and automatic. Manual segmentation is the base method for lesion segmentation. An expert physician examines different modalities to select the lesion pixels. Unfortunately, the manual process is time consuming and somewhat subjective. Still, manual segmentations are considered the best results available and serve as the baseline for evaluating other methods. The expert segmentations can be considered a "silver standard" since they are not perfect representations of the ground truths, but provide the best in-vivo estimates available. Computer-aided methods do provide some benefit to MS lesion segmentation, where experts can have difficulty combining information from multiple MRI modalities and from multiple ad-

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jacent slices; well-designed algorithms can efficiently blend this data. As a result, it is important to focus on the development of semi-automated and automated lesion segmentation methods. Automatic segmentation offers an attractive alternative to manual segmentation which remains a time-consuming task and suffers from intra-expert and inter-expert variability. However, the progression of the MS lesions shows considerable variability and MS lesions present temporal changes in shape, location, and area between patients and even for the same patient.

The objective of research work included in this paper is to provide a robust technique for automatic segmentation of multiple sclerosis lesions from brain MR images. Most of segmentation techniques in the literature suffer from high false positives due to the similarity between MS lesions and the normal tissue and also due to basing the learning on pixels while the lesions form regions. Comprehensive study of false positive and negative in MS segmentation is needed with proposed segmentation technique or any other technique to provide more accurate and clinical friendly results. The proposed technique is designed mainly for MS lesions detection and the different tissues of the brain are not segmented. Proposed method has generates the background for each image. Three phase level set is the key idea to generate backgrounds for each image. Contour detection performed after artifact and skull removal image. Then we add the level set image and the contour image to generate adaptive background. To detect MS lesion a global threshold selection methodology has been done by the combination of entropy and standard deviation. Then the binary threshold generated image is subtracted by background image and finally the MS lesion is obtained. This approach captures the neighboring lesion properties and produces encouraging results, with a general improvement in the detection rate of lesions.

The rest of the paper is organized as follows. Literature review on some existing method has been described in Section 2. The proposed methodology has been described in Section 3. Detailed results and comparison with some recent superior methods has been described in Section 4. Finally, we conclude our method in Section 5.

2. Review work

Today more than 2300,000 people around the world are affected in MS [3] disease. Symptoms vary widely including blurred vision, weak limbs, tingling sensations, unsteadiness and fatigue. For some people, MS is characterized by periods of relapse and remission while for others it has a progressive pattern. There exist some general categories for automated segmentation of MS lesions in MRI scans of the brain. The methods can be broadly categorized on the approach and grouped based on their implementation [4]. Conventional methods are limited by lack of pathological specificity and lack of sensitivity to gray matter lesions and to microscopic damage in normal appearing white matter, which can also be associated with other chronic inflammatory diseases of the CNS [5]. Focal cortical lesions are typically not seen on some conventional method as they are smaller in size and have poor contrast with the surrounding normal gray matter, in addition to partial volume effects from the CSF [6]. Lorenzo et al. (2009) [7] proposed an automate multimodal graph cuts in order to automatically segment MS lesions in MRI which replace the manual interaction in order to discriminate between MS lesions and the normal appearing brain tissues. Evaluation is performed in synthetic and real images showing good agreement between the automatic segmentation and the target segmentation. It is observed with an example of semi-automatic edition of our automatic segmentation. When a lesion is missed, a user can add a seed, in this case a source seed, and the graph cuts are recomputed in few seconds. Derraz et al. (2010) [8] proposed a semi-automatic segmentation based active contour model and statistic prior knowledge of MS Lesions that can find in regions of interest within brain MRI. The authors [8] showed a significant improvement of the proposed model but it suffers from over segmentation problem. But it is useful for interactive segmentation due to its high performance and the facility to add or remove training prototypes to improve the results.

Forbes et al. (2010) [9] proposed an augmented multi-sequence hidden Markov model that includes additional weight variables to account for the relative importance and control the impact of each sequence. The augmented framework has the advantage of allowing 1) the incorporation of expert knowledge on the a priori relevant information content of each sequence and 2) a weighting scheme which is modified adaptively according to the data and the segmentation task under consideration. The model, applied to the detection of multiple sclerosis and stroke lesions shows promising results. But investigating other settings, particularly in relation to targeting specific lesion types is limitation of that method [9].

Derraz et al. (2014) [10] proposed to develop and evaluate an automated lesion segmentation method based on Active Contours (AC) model incorporating tissue knowledge issued from T1-weighted and tissues distribution on FLAIR image. The GM and WM as well as CSF tissue classes issued from T1-weighted and the tissues intensities issued is used in order to determine an automatic outlier of each tissue class is used in order to detect outliers. Neither training nor thresholding is needed to performed the fully automatic segmentation based AC and outlier. Another advantage of our approach lies in the fact that it involves no thresholding step. Without explicit modeling, either soft or hard rejection, a predetermined threshold has to be used to decide the separation between the normal tissue and the outlier pixels. Since the thresholds are often data-dependent, manually chosen values tend to not work consistently across different data sets.

Cabezas et al. (2013) [11] proposed a pipeline method for MS lesion segmentation that combines prior knowledge and contextual information into a boosting classifier. The prior knowledge was introduced in terms of atlas distribution of the main brain tissues. The contextual information was based on a large set of features describing the spatial context in the lesion neighborhoods. The experimental results obtained with two datasets from two different hospitals were shown a better segmentation was obtained using the extended outlier map as a feature in conjunction with the classical and contextual features. Still some improvement is needed in terms of specificity as a common issue.

Geremia et al. (2013) [12] used segmentation problem that formalized as a binary classification of pixels samples into either background or lesions. It takes the advantages of context-aware features in the classification task to detect the differences in appearance of MS lesions with respect to healthy brain tissue. Subsequently, Geremia et al. (2013) [12] used the classification forest technique for MS lesion segmentation. But over segmentation occurred when MS lesions like similar intensity appears. Biediger et al. (2014) [13] used a strategy to improve the segmentation results of an automated system on whole-brain tissue classification and lesion detection. The first strategy leverages the current processing system at a granularity finer than the whole brain to detect lesions at a local level. This reflects the way that a physician considers only a part of the brain at a time. Then it combines the series of local results to produce whole-brain segmentation. This approach better captures the local lesion properties and produces encouraging results, with a general improvement in the detection rate of lesions. The second method dives deeper and looks at the individual pixels level. But spurious lesion generation is the one of the disadvantage of this method.

Mechrez et al. (2016) [14] presents an automatic lesion segmentation method based on similarities between multichannel patches. A patch database is built using training images for which the la-