CHAPTER 2

An Automatic White Matter Hyperintensity (WMH) Identification and Classification

Siti Noraini Sulaiman, Iza Sazanita Isa, Siti Noraini Sulaiman, Muzaimi Mustapha, & Noor Khairiah Ab Karim

University Teknologi Mara

Abstract

The white matter hyperintensities (WMH) is commonly associated with various disorders. Several researches prove that WMH is determined to be a strong risk factor for stroke. There are vast amount of researches conducted to observe WMH on T2-weighted imaging (T2-WI) and FLAIR (Fluid-attenuated inversion recovery) sequences. This paper introduces a new method for automatically segmenting WMH from T2-WI and FLAIR sequences of MRI (magnetic resonance imaging) images. The approach is based on intensities and contrast mapping on one image sequence while segmenting WMH on another sequence. Both sequences are then integrated by overlying the maps in order to identify most precise WMH areas. Accuracy of the WMH ROI (region of interest) identification is accessed through the percentage of correct detection, branching factor and quality of segmented images. The result shows that this method is achievable by 88% ability to detect correct WMH area and the quality measure is about 83% of all WMH ROI.

Introduction

The objective of this work is to determine the precision and accuracy of an automatic WMH detection by segmentingWMH ROI on MRI (T2-weighted imaging and FLAIR) images in brains at 1.5T. The overall proposed method to automatically identify WMH ROI as shown in flowchart of Fig 1.

The system is divided into three parts to respectively process two MRI axial modal, T2-WI and FLAIR images. The first step namely as part A is segmentation mapping of T2-WI images where only the WM region was segmented from the image. Meanwhile, the average intensities of each region (GM, WM, and CSF) were also measured to justify their mean intensities distribution.

Part B is mapping by using image contrast enhancement on FLAIR image. The high intensity area on FLAIR images was enhanced so that the WMH is easier to be detected. The left-over on the images was the ROI which have the maximum intensity presents the potential WMH ROI. The last part C is used to integrate both maps from Part A and Part B. The WM map and potential WMH ROI was overlaid altogether so that the most precise area of WMH is determined.

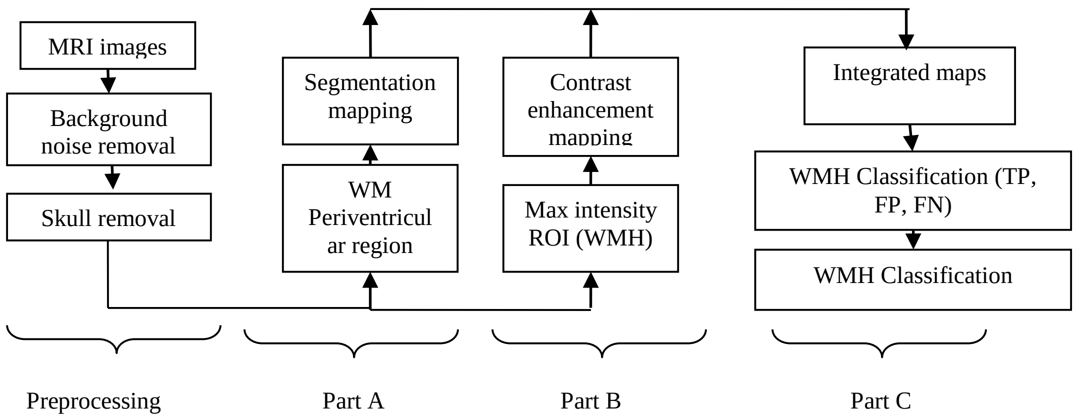

Fig. 1: Flowchart of automatic WMH identification

Methodology

At initial, image pre-processing is applied to remove noise background which has been affected during imaging process. As the MRI image was usually presented in gray image (it's actually not in grayscale format), the noise is tend to be negligible and ignored. But once the image is presented in indexed images, the noise can be seen clearly attached around the brain. Mean while, the skull was also removed leftonly the important regions to make the image processing much easier. The process of skull removal was implemented using fundamental MATLAB image processing toolbox such as binarize, eroded, dilated and mask image.

Segmentation Mapping

This part is processing the T2-WI image to segregate only WM periventricular region. Fig 2 presents the overall process of part A. The image was segmented into 4 clusters to represent image background, white matter, gray matter and skull/other tissues using k-means clustering algorithm.The mean intensity of each clustered regions were measured to identify their grayscale level of intensity. At final, the image was again segmented into two clusters which represent WM region and potential WMH region.

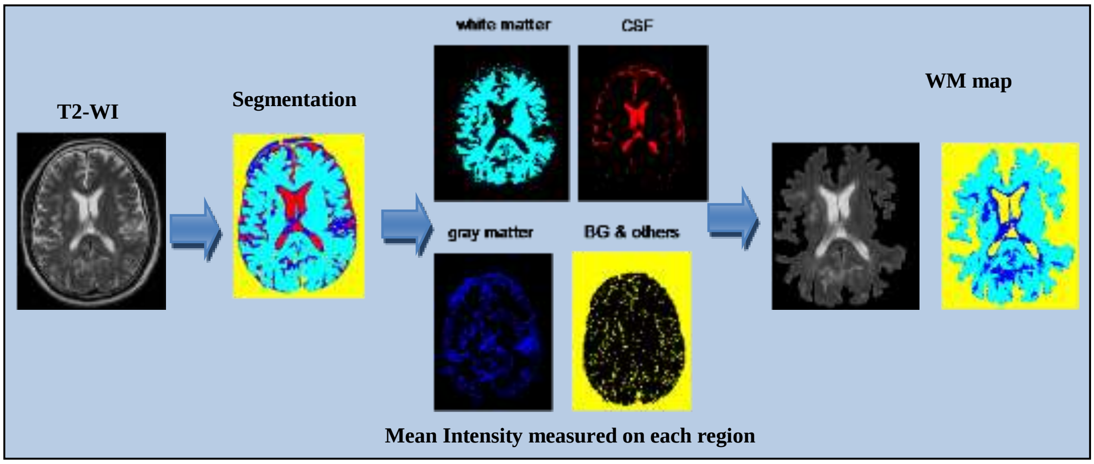

Fig. 2: WM periventricular region mapping process

Contrast-based Enhancement

This part processed axial modal of FLAIR image since fluid and fat were suppressed on this sequence and high contrast on WM and GM regions can be easily detected. To improve the contrast of potential WMH, the image was enhancing by using Adaptive Histogram Equalization. Adaptive Histogram Equalization (AHE) improves on this by transforming each pixel with a transformation function derived from a neighborhood region.The regional maxima function has been applied in order to determine higher intensity location in WM region. Regional maxima are connected components of pixels with a constant intensity value, and whose external boundary pixels all have a lower value. The function returns the binary image that identifies the locations of the regional maxima in image. In binary image, pixels that are set to 1 identify regional maxima while all other pixels are set to 0. Fig 3 demonstrates the process of improving the contrast of WMH in WM region.

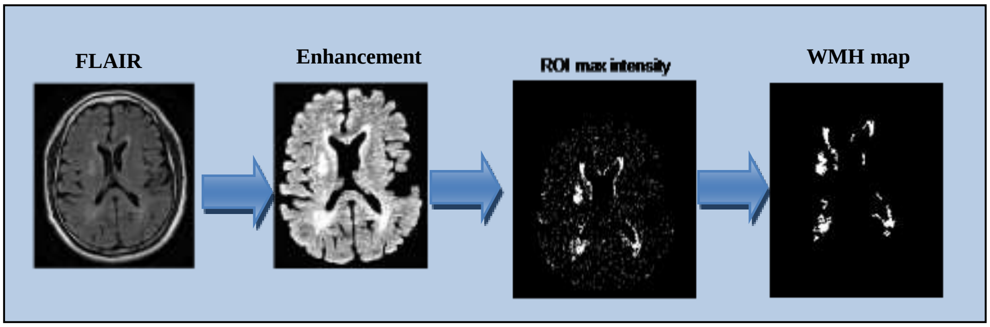

Fig 3: WMH contrast-based enhancement mapping process

Mapping / Integrated Images

This part was used to integrate both sequence from part A and part B by overlaying the images. Both sequences of images were converted into true color so that the overlaid region is able to differentiate. As seen in Fig 4, the true positive (TP) of WMH area is presented by purple color (overlay between blue and red).

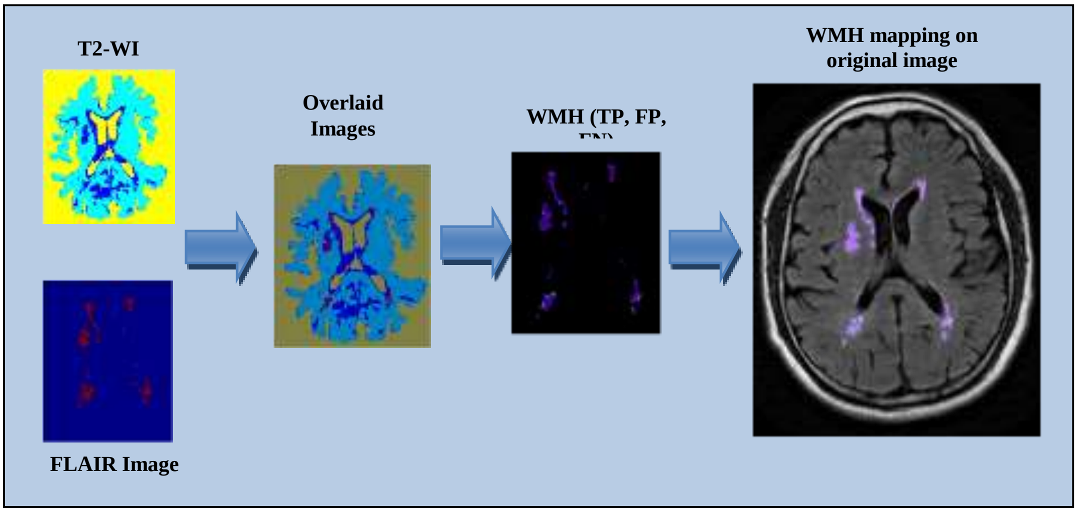

Fig 4: Integration of mapping images

Results

This work implemented single slice of MRI axial mode from T2-WI and FLAIR images. The grayscale intensities level of each region was measured and tabulated in Table 1. The CSF region has the highest intensity of 156 followed by GM with 107 and WM region is 64. This measurement has similar comparison with the original image. As we can see, the CSF region shows the brightest which almost white, followed by GM and WM. For this work, the evaluation method used by determining percentage of correct detection, branching factor which taking measurement on the over-detection pixels and percentage of quality for WMH ROI detection. The results show that this method is achievable to detect correct WMH severity on WM region by 88% accuracy. While the over-detection of WMH is relatively low as 0.079 out of maximum value 1. The percentage of quality to detect true WMH severity is 83%.

Table 2 is showing all the potential WMH regions which has been mapped between two axial imaging T2-WI and FLAIR sequences. For this slice, there are 16 points of potential WMH detected with total area of 1622 (pixels). Then, each potential WMH is classified based on number of pixels on overlapped area by considering the referral study (Wen and sachdev, 2004) as the main reference. On their study, they have classified WMH cluster into 3 types according to the number of WMH voxels. The classification is much related to visual quantification provided by Fazekas scaleas. The result shows that mean intensity of WMH region is around 96.76 and based on the pixels, the WMH severity is classified as class 2.

Table 1
The grayscale mean intensity of brain regions

Overall brain region (min - max)	Area (pixels)	79833
	Mean intensity	88.0569 (0-255)
WM region	Area (pixels)	47405
	Mean intensity	63.8186 (4-82)
	Standard deviation	9.685
GM region	Area (pixels)	16176
	Mean intensity	107(96-122)
	Standard deviation	9.24
CSF region	Area (pixels)	8720
	Mean intensity	156(145-172)
	Standard deviation	7.75

Table 2
WMH ROI classification

WMHs	Area in Pixels	mean intensity	min intensity	max intensity	Class (pixel based)
1	21	88.14	79	97	3
2	424	95.21	73	120	3
3	285	83.29	71	97	3
4	338	92.27	71	131	3
5	28	114.43	85	147	2
6	2	80.50	79	82	1
7	42	93.00	77	119	2
8	25	106.88	80	145	2
9	3	86.00	86	86	1
10	4	127.75	119	141	1
11	9	121.78	107	147	1
12	142	93.42	68	146	3
13	23	109.61	80	144	2
14	224	83.81	70	111	3
15	45	83.40	71	100	2
16	7	88.71	79	103	1
Mean intensity		96.76	80.94	119.75	
Total WMH area	1622		Mean class		2

Conclusion

As aconclusion, this new approachhas successfully segment the WMH region of MRI images using automatic method based on intensities and contrast mapping. The accuracy of WMH detection is achievable by 88%. For future works, all the sequences in T2 and

FLAIR images will be implemented using this approach. In order to improve the percentage of WMH correct detection, further works on algorithm development and alteration will be conducted.

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