2D-Sigmoid Enhancement Prior to Segment MRI Glioma Tumour

Pre Image-Processing

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Abstract— **Tumour identification has always been a topic that interested researchers around the world. The most challenging phase in tumour identification based on brain MR image is the segmentation of the tumour contour which may contain many unwanted details. Intensity inhomogeneities often occur in real world images and may cause the difficulties in image segmentation. In order to overcome the difficulties caused by intensity inhomogeneity, the study presented pre-processing prior to a region based active contour model with modification of Region Scalable Fitting (MRF) method for image segmentation. Region based active contour model that draw upon intensity information in local regions. The pre-processing is a kind of image enhancement which applies the 2D-sigmoid function at tumour boundary. 2D-sigmoid function enhances the contrast in the brain MRI image for pre-processing steps. Enhanced pixel value, *F(x, y)*, is the 'S' shape function of intensity *I (x, y)* of the image at the point *(x, y)*, width of the gradient magnitude around brain image (α) and gradient magnitude around brain image (β). Experimental results show desirable of MRF method in terms of computation efficiency.**

Keywords—tumour; inhomogeneity; brain image; 2D-sigmoid

I. INTRODUCTION

Medical segmentation of brain tumour still faces difficulties in its implementation. These difficulties arise from noise, low image contrast, intensity homogeneity and also missing, non-clear edges of tissue in the images which can be due to patient movements and poor signal to noise ratio of image acquisition devices. This paper will discuss the difficulties that arise from noise, low image contrast and intensity homogeneity to make the segmentation of brain tumour.

The most commonly used imaging method for diagnosis in and follow up are computed axial tomography (CT) scan or Magnetic Resonance Imaging (MRI) scan. An injection of a special contrast material (dye) to make abnormal tissue more obvious is usually given during the scan. The contrast materials concentrate in diseased tissues in greater quantity than in healthy tissues due to the leakiness of blood vessels in and around brain tumours. It highlights abnormalities such as tumours.

MRI brain scan is less harmful than CT brain scan because MRI uses magnetic field and radio waves to produce detailed images of the brain and the brain stem. MRI allows more accurate determination of tumour location compared to CT scan [1]. MRI offers images with anatomical detail which provides clarity of the small structures in the brain, but the images often lack quantitative or finely measurable, information. As a general rule, MRI studies of the brain should include at least two imaging planes and two "weightings," and preferably more. MRI sequence is an ordered combination Radio Frequency (RF) and gradient pulse designed to acquire the data to form the image.

The data to create an MRI image is obtained in a series of step. *Firstly,* the tissue magnetisation is excited using and RF pulse in the presence of a slice select gradient. *Secondly*, the phase of encoding and frequency encoding/read out are required to spatially localise the protons in two dimensions. *Finally,* after the data have been collected, the process is repeated for a series of phase encoding step. MRI sequence parameters are chosen to best suit the particular medical application. The different sequences often provide different contrast between tissue so the most appropriate sequence should be chosen according to disease and what the clinicians want to detect. Table 1.1 below provides an overview of (some) standard sequences for MRI of the brain.

TABLE I. OVERVIEW OF SEQUENCES OF MRI BRAIN IMAGES

Types	Description
T1	Contrast depends predominantly on the differences in the T1 times between tissues e.g. fat and water.
T2	Contrast predominantly depends on the differences in the T2 times between tissues e.g. fat and water.
FLAIR	use a long TI (eg: 2000 ms) and a short TR (eg: 10 ms) to suppress the signal from water.
STIR	Inversion recovery pulse sequence that uses a TI that corresponds to the time it takes fat to recover from full inversion to the transverse plane so that there is no longitudinal magnetisation corresponding to fat.

[a] The sequence may vary in other hospital

The intensity inhomogeneity often occurs in real images. The inhomogeneity in MR images arise from the non-uniform

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magnetic fields produced by radio-frequency coils as well as from variations in object susceptibility. Segmentation of such brain MRI usually requires intensity inhomogeneity correction as a pre-processing step. Li et.al [2] proposed Local Binary Fitting (LBF) and Region Scalable Fitting (RSF) to handle the intensity inhomogeneity. However, Zhang, Song, Zhang [3] found that LBF has high computational complexity in the term of data fitting and RSF is sensitive to initialization.

Therefore, the process of the segmentation must be accurate and repeatable in order to be clinically useful. Exact region or boundary of tumour is important for radiologist in order to get the exact size and shape of the tumour for surgery process. The accuracy of radiologist's result can be increased by doing image segmentation on MRI brain image. The size and shape of the tumour includes the width and height of the tumour growth. Based on this information, the radiologists can identify the types of tumour that appeared in MRI image whether it is malignant or benign.

In order to get the desired quality of the images before the segmentation process, the pre-processing image is required. This paper reports this pre-processing the MRI brain image and the objective of this research is to enhance the quality of brain MRI images by applying the two dimensional (2D) of sigmoid function.

II. SIGMOID FUNCTION

Previous research of Hassan and Akamatsu [4] has found new approach for dealing with the low image contrast using sigmoid function. Contrast enhancement is a process that allows image features to show up more visibly by making the best use of the colours presented on the display device. The research prepared a mask based on the input parameters by using non-linear activation function that is sigmoid function. Sigmoid function is a continuous non-linear function and also known as logistic function. Sigmoid derives from the fact that the function is "S" shaped.

Using *f(x)* for the input and *g(x)* as a gain, the sigmoid function is Equation (1).

$$f(x) = \frac{1}{1+e^{-g(x)}} \tag{1}$$

By motivation from the past research, the sigmoid function has been used in the pre-processing step.

III. IMAGE ENHANCEMENT WITH MODIFIED SIGMOID FUNCTION

Image enhancement techniques have been commonly used in various applications where the quality of images is important. The flowchart of the image enhancement has shown in Figure 1 below:

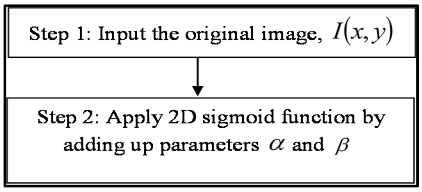

Fig. 1. Flowchart of Image Enhancement

In image pre-processing, especially in tumour segmentation, there are two steps for edge enhancement of T2 sequence of brain MRI images.

Step 1: Input the original image, $I(x, y)$. MRI brain image that contain tumour is used in this study. MRI brain images are already in greyscale.

Step 2: Apply sigmoid function by adding up parameters α and β .

The sigmoid filter is used to highlight a range of intensities of the brain region or improve the low contrast image. It is often used as a pre-processing step before segmentation algorithms. With appropriate choice of parameters, the sigmoid filter is considered as a contrast enhancement filter [4]. Referring to their works, original sigmoid function is in one-dimensional which involves x-coordinates n Equation 1 above, *f(x)* input function in terms of *x*. and *g(x)*: gain function in terms of *x*.

The image pixel contains two variables which *x*-coordinates and *y*-coordinates, *I(x,y)* . On the other hand, the 1D-sigmoid function can be rewritten as 2D-sigmoid involves *x, y* coordinates. *F(x, y)* is a transformation function which enhanced the pixel value. A transformation of the image grey levels is applied to the whole brain image such that the pixels with the same gray level at difference places in the original image are still kept the same in the processed image [5].

The intensity values in an image using can be adjusted with function, and the range of intensity values in the output image will be specified. For example, this code increases the contrast in a low-contrast grayscale image by remapping the data values to fill the entire intensity range [0, 255]. The 2D-sigmoid function involves parameter values of α and β . The parameters α and β is used to control exaggerating of intensity differences between tumour and other tissue in brain. The value of parameters depends on the objective of the enhancement process, the user can select the value of α and β according to the desired contrast that he needs.

Substitute $I(x, y)$, α and β in Equation (1), gives

$$f(x, y) = \frac{1}{1+e^{-\left(\left(\frac{I(x,y)-\beta}{\alpha}\right)\right)}} \tag{2}$$

Where

$f(x, y)$: enhanced pixel value.

$I(x, y)$: intensity of the image at the point (x, y).

α : width of the gradient magnitude around brain image.

β : gradient magnitude around brain image.

The control parameters of sigmoid filter are α and β where the parameter values limit must be specified before the segmentation is applied. The value of both parameters should within limited range (0-255) for an 8-bit image. After the pre-processing step, the initial tumour region has been identified by the proposed segmentation technique. After the edges of the tumour have been enhanced by the above filter, the tumour region has been segmented by using modification of region fitting.

IV. Pre-Processing Result

The contrast in MRI images is in grayscale and could be high or low (bright or dark). The scale very depends on the sequence used, and the type of the tissue in the image region of interest. The grayscale of the MRI image depends on the density of proton in that area. Relaxation times for proton can vary two times commonly measured in the T1 and T2 sequences. The contrast provided by white matter is darker than the grey matter in T1 weighted images and brighter than grey matter in T2-weighted images. This study of the MRI brain image is based on the T2 sequences which this sequence contains fat, water and fluid in the bright side.

The true colour (RGB) original image is 200 x 200 x 3 as three dimensional array of integers in the range [0 255]. The value of 3 shows the image is already greyscale image. The indexed (colour map) of pixel is 200 x 200. Each pixel has a pixel value which describes the brightness of the pixel. For greyscale image, the pixel value is a single number that represents the brightness of the pixel. The most common pixel format is the byte image where the numbers are stored as an 8-bit integer giving a range of possible values from 0 to 255. Typically zero is taken to be black and 255 are taken to be white. Each pixel value denotes the intensity of light at that point of the image.

In this research, the sigmoid function transforms the pixel value for each pixel where value of black colour will turn to white. The transformation can be seen in the pre-processing step. The aim of image enhancement is to make features of the tumour image much easily seen by modifying the intensities of tumour brain image. For example, the image in Figure 2(a) shows the T2-weighted MRI original image of brain tumour. Figure 2(b) shows the image enhancement using sigmoid function as contrast enhancer.

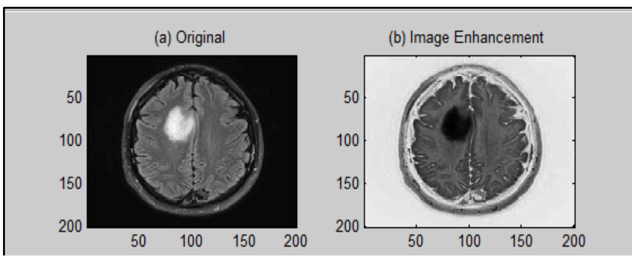

Fig. 2. Image Enhancement of Tumour 1

The image enhancement in Figure 2 represents clear contour of glioma tumour. The values of control parameters in Equation (2) are α and β. The chosen parameter values are based on the pixel value in Tumour 1. For example, the intensity value in original image at tumour is around 200 to 255. After applying the sigmoid function, the enhanced pixel value, is around 0 to 0.5. Equation (2) transforms the brightness of tumour region in Figure 2 become darker where the intensity value for each pixel in tumour region becomes 0. The smooth contour of tumour image assists the radiologist to segment the initial tumour region.

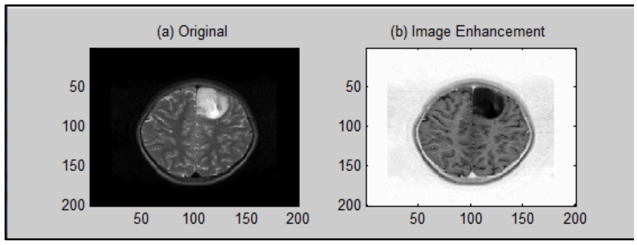

Fig. 3. Image Enhancement of Tumour 2

Figure 3 shows the image enhancement by using sigmoid filter which the values of control parameters are $\alpha = 100$ and $\beta = 225$.

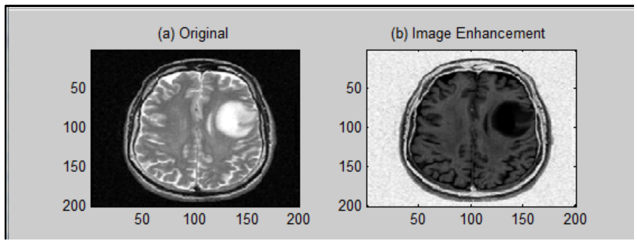

Fig. 4. Image Enhancement of Tumour 3

Figure 4 represents the image enhancement by using sigmoid filter which the value of control parameters are $\alpha = 110$ and $\beta = 225$.

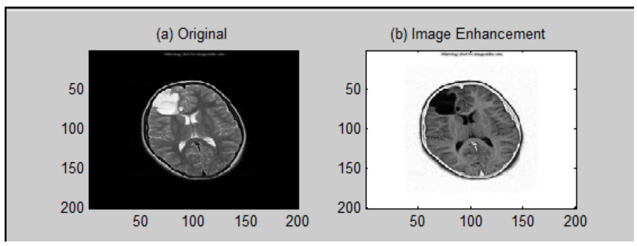

Fig. 5. Image Enhancement of Tumour 4

Figure 5 shows the image enhancement by using sigmoid filter which the value of control parameters are $\alpha = 120$ and $\beta = 225$.

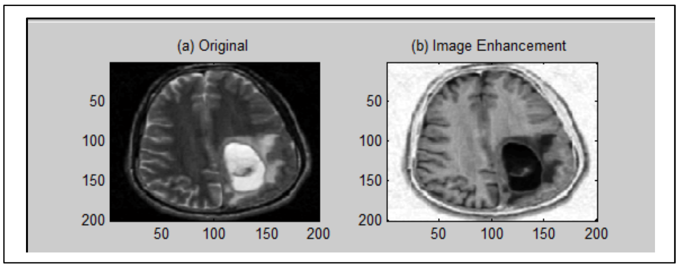

Fig. 6. Image Enhancement of Tumour 5

Figure 6 shows the image enhancement by using sigmoid filter which the value of control parameters are $\alpha = 100$ and $\beta = 225$.

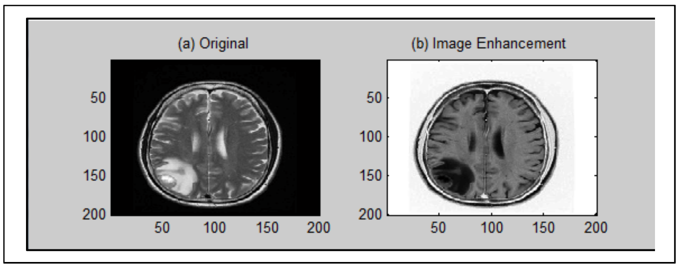

Fig. 7. Image Enhancement of Tumour 6

Figure 7 shows the image enhancement by using sigmoid filter which the value of control parameters are $\alpha = 110$ and $\beta = 225$.

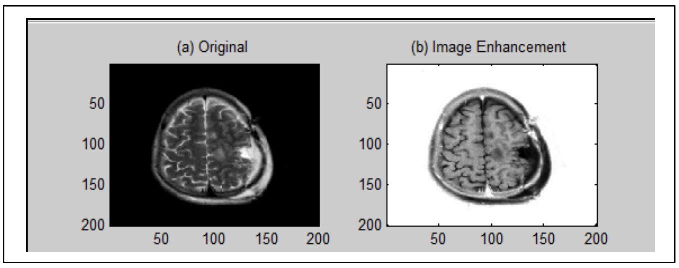

Fig. 8. Image Enhancement of Tumour 7

Figure 8 shows the image enhancement by using sigmoid filter which the value of control parameters are $\alpha = 110$ and $\beta = 245$.

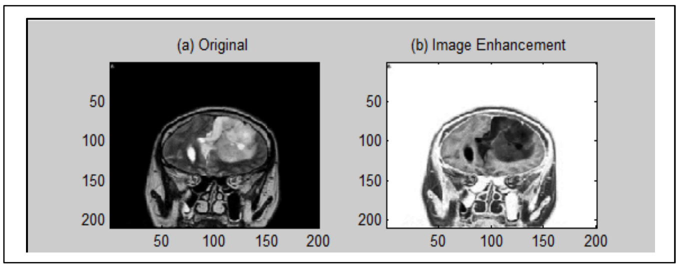

Fig. 9. Image Enhancement of Tumour 8

Figure 9 shows the image enhancement by using sigmoid filter which the value of control parameters are $\alpha = 150$ and $\beta = 245$.

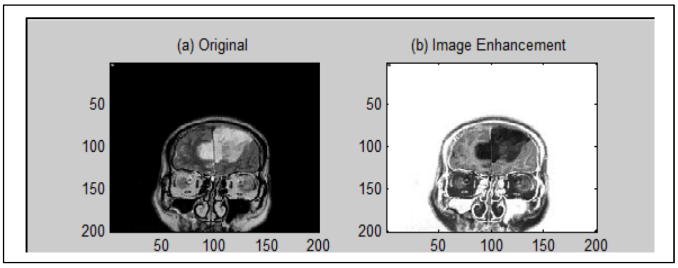

Fig. 10. Image Enhancement of Tumour 9

Figure 10 shows the image enhancement by using sigmoid filter which the value of control parameters are $\alpha = 150$ and $\beta = 240$.

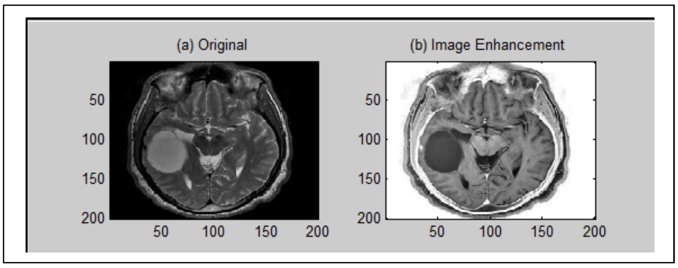

Fig. 11. Image Enhancement of Tumour 10

Figure 11 shows the image enhancement by using sigmoid filter which the value of control parameters are $\alpha = 100$ and $\beta = 245$.

After applying the proposed enhancer, most of the tumour regions have become discriminated and more interpretable to the human eye. The resulting images from the proposed enhancer has a much higher readability than its original form and prove highly effective in dealing with low contrast images. It could give high contrast images and the boundaries of each tumour region in the processed images are clearly highlighted. From the results above, the study found that by 2D-sigmoid function, the study can easily improve the contrast darkness and the brightness of the poor images without affecting the details or introducing the amount of noise to the output images. Therefore, the process of image segmentation and classification of tumour region can be powerfully accomplished from the resulting images.

V. COMPARISON OF MODIFIED REGION FITTING (MRF) METHOD AND REGION SCALABLE FITTING (RSF) METHOD

To see the performance of MRF method, the study analyses the number of iterations of RSF and MRF methods. The summarization of the number of iterations can be seen in Table II and Table III.

TABLE II. COMPARISON OF THE NUMBER OF ITERATIONS BETWEEN RSF AND MRF METHODS OF TUMOUR 1 TO 5

	Tumour1 200 x 200 pixel	**Tumour2** 200 x 200 pixel	**Tumour3** 200 x 200 pixel	**Tumour4** 200 x 200 pixel	**Tumour5** 200 x 200 pixel
RSF	450	350	520	720	320
MRF	380	340	450	700	300

Based on the results in Table II, the MRF method takes less the number of iterations than RSF method. The experiments use the same values of parameters. Therefore, MRF method is better than RSF to segment the initial region of brain tumour images.

TABLE III. COMPARISON OF THE NUMBER OF ITERATIONS BETWEEN RSF AND MRF METHODS OF TUMOUR 6 TO 10

	Tumour 6 200 x 200 pixel	**Tumour 7** 200 x 200 pixel	**Tumour 8** 200 x 200 pixel	**Tumour 9** 200 x 200 pixel	**Tumour 10** 200 x 200 pixel
RSF	1550	1600	920	960	420
MRF	1500	1500	900	1000	415

Based on the results in Table III, most of the MRF method takes less the number of iterations than RSF to segment the optimal final contour of tumour 6 to 10. The modification of fitting functions and data fitting term reduce the re-initialization of RSF method. Therefore, MRF method achieves the objective to reduce the computational cost in data fitting term in RSF method.

VI. CONCLUSION

The study has proposed a simple but effective region-based active contour model for segmenting MRI brain tumour. The proposed method introduces a two-dimensional sigmoid function which enhanced the MRI brain image that contains noise. The proposed contrast enhancer is fast, easily implemented and is a simple way to adjust image's tonal range without sacrificing brain images detail. For the segmentation of final contour of tumour, the proposed method applies the 2D-sigmoid function into a local fitting energy proposed by Li et. al. [2]. The modified data fitting term in local fitting energy is utilized to address the intensity inhomogeneity. Meanwhile, the modified data fitting term allows the method to deal with noise. When minimizing the proposed energy function, the image is approximated by local intensities inside and outside the active contour. This method could segment other medical images with intensity inhomogeneity even with weak boundary or noise. The experiments have been done for 10 MRI brain images which contain brain tumour.

ACKNOWLEDGMENT

This research was partially funded by Ministry of Higher Education (MoHE), Department of Higher Education (JPT), Institutions of Higher Education Excellence Planning Division (BPKI) Fundamental Research Grant Scheme (FRGS/1/2016/STG07/) – Pure and Applied Science.

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