MORPHOLOGICAL – WATERSHED ALGORITHM FOR MRI BRAIN TUOMOR SEGMENTATION

PHÂN ĐOẠN KHỐI U NÃO MRI DÙNG THUẬT TOÁN HÌNH THÁI HỌC VÀ PHÂN CHIA NƯỚC

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ABSTRACT

Tumor in the brain is a deadly and intractable disease. Therefore, brain tumor detection and segmentation have played a vitally important role for helping doctors in the process of diagnosis and treatment. Moreover the earlier tumor is detected, the easier treatment is. However, there are some problems for detecting the brain tumor in the early stage, such as: the tumor is not clear, the quality of the MRI images is not suitable, or noise appears in the images. Therefore, this paper proposed a method of segmenting MRI brain tumor image based on the combination of Sobel filter, morphological operator and watershed algorithm. In particular, the Sobel mask will be used for tumor edge detection, then dilation operator is applied to link all dashed tumor boundaries, before the watershed algorithm is implemented to detect and segment the tumor regions. Finally, depending on the watershed transformed image, the tumors are clarified in the result image. With this proposed technique, the tumor segmentation processing is implemented automatically, the location and the shape of brain tumors can be simply detected visually and the time consumption for diagnosis is reduced.

Keywords: *image segmentation, MRI brain tumor image, Sobel mask, morphological operators and watershed algorithm.*

TÓM TẮT

U não là một căn bệnh nguy hiểm và khó điều trị. Vì vậy, phát hiện và phân đoạn khối u não đóng một vai trò cực kì quan trọng để giúp bác sĩ trong quá trình chuẩn đoán và điều trị bệnh. Khối u càng được phát hiện sớm, thì việc điều trị càng dễ dàng. Tuy nhiên, cũng có nhiều khó khăn gặp phải trong quá trình phát hiện ở giai đoạn tiền phát triển khối u, cụ thể khối u vẫn chưa phát triển rõ ràng, chất lượng ảnh cộng hưởng từ (MRI) không tốt hay nhiễu xuất hiện trong ảnh được phân tích. Do đó, một phương pháp phân đoạn ảnh khối u MRI được đề xuất để làm rõ khối u. Trước tiên, mặt nạ Sobel được sử dụng để phát hiện biên của khối u, sau đó phép toán hình thái học được dùng để liên kết các nét đứt trên đường biên của khối u. Tiếp đến là thuật toán phân chia nước (watershed) được thực thi để phát hiện cho phân đoạn vùng não chứa khối u. Cuối cùng, dựa trên ảnh biến đổi watershed, khối u được làm rõ trong ảnh kết quả. Với kĩ thuật được đề xuất, quá trình phân đoạn khối u được thực thi vị trí và hình dáng khối u não có thể được phát hiện một cách trực quan.

Từ khóa: *phân đoạn ảnh, ảnh MRI u não, mặt nạ Sobel, phép toán hình thái học, thuật toán watershed.*

1. INTRODUCTION

The smart devices such as phones and computers have rapidly emerged to human life. The effects of radiation, therefore, increasingly affect humans. In addition, industries such as pesticides, solvents mixing, dyes, oil refineries, rubber manufacturing, pharmaceutical manufacturing have been developed variously. All these reasons can lead to the increasing of pollution, human diseases including brain tumors. Therefore, tumors in brain are very dangerous. Therefore, early detection of tumors is quite important to makes treatment easier. However, a difficulty arises in the early stage that the tumor is not clear, the symptoms are less shown on image or the unsatisfactory images, causing the difficulty in diagnosing, detecting tumors with the naked eye.

In practice, many medical image processing methods are proposed to serve for early detection of tumors in the early stage. In practice, there are three types of tumor: benign, pre-malignant and malignant. A lot of tumor diagnosis is done by CT scan, MRI or combination of two types [1] [3].

There have been many research endeavors to segment brain tumor in MRI in recent years. A fast boundary boxing algorithm was used to develop an automatic system for brain tumor detection [2]. An ISM-based fuzzy c-means clustering brain image segmentation in color MRI image was proposed by Yong Wei [4]. K-means clustering algorithm also can be used to determine the tumor region [6]. Another technique was used to detect and segment the brain tumor region based on morphological operators, watershed transformation [5] [7-11].

In this research, an effective brain tumor segmentation technique is proposed by using the combination of Sobel filter, morphological operator and watershed transformation. The advantages of this method are that it can determine the tumor region clearly and be automated.

For more details, the following sections will give a better explanation with the proposed method, simulation results, discussion and conclusion.

2. PROPOSED METHOD

The proposed work implements a system for detecting the tumor using various steps as described in Fig. 1. Firstly, MRI images are converted to gray images and then performed pre-processing, including inscription rejection, noise rejection, image enhancement. After that, normal parts of the brain are eliminated then image gradient transformation is implemented. And the morphological operator (dilation operator in detail) is used in order to connect discontinuous tumor margin. Similar pixels are clustered to segment brain tumors by using watershed transformation. After that, the watershed transformation image and the original image are combined to obtain the result image with highlighted tumor region.

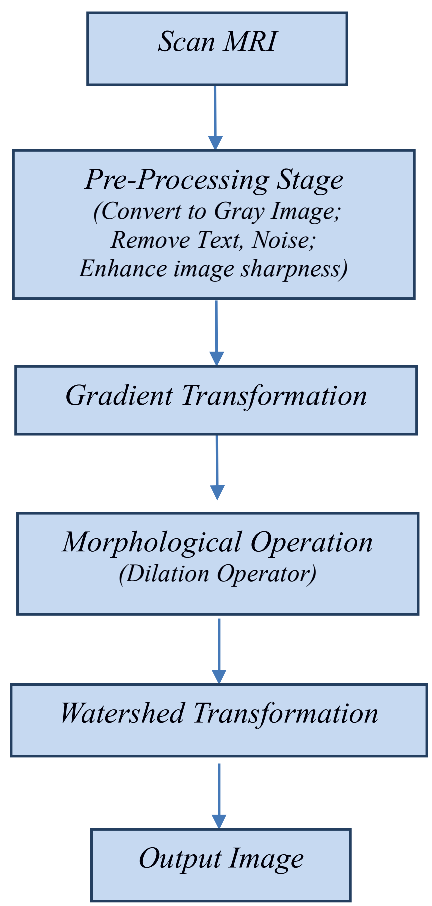


***Figure 1**. Block diagram of Tumor image*

segmentation.

Fig. 1 is the step-by-step flow to detect and segment the tumor used in this paper. The proposed tumor processing includes: pre-processing, gradient transformation, morphological operation (dilation operator), watershed transformation, and output image with detected tumor region.

2.1 Image Pre-processing

Dataset with the total 35 MRI brain tumor and normal images (288x288 pixels) are used for analysis in this research, in which these MRI brain images are supported by Quang Ngai General Hospital.

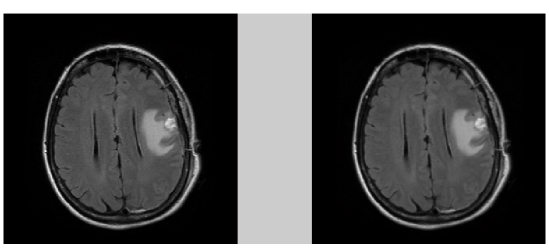
In this phase, image quality is enhanced and noise is removed from the image. A RGB image should be converted to the gray image by eliminating the hue and saturation information while retaining the luminance using the following formula:

Glev = 0.2989*R+0.5870*G+0.1140*B (2.1)

where Glev is a gray-level after converting from the RGB image.

After removing unwanted text-noise (if any), a low pass filter $H(\mu, v)$is applied to remove noise in the image using the following equation:

$$H(\mu, v) = \begin{cases} 1, \sqrt{\mu^2 + v^2} \leq R \\ 0, otherwise \end{cases} \quad (2.2)$$



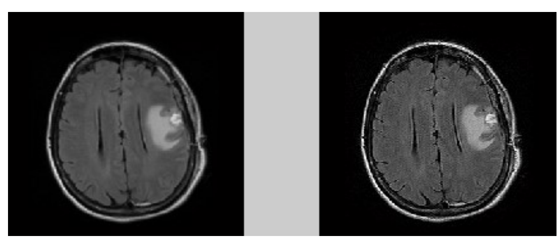
(a) (b)

Figure 2. *Image with noise removed: (a)_Original brain tumor image; (b)_ Image after filtering.*

Fig. 2 is the result from perform the convolution operation between the source image and a 3-by-3 kernel $\begin{bmatrix} 0 & 1/8 & 0 \\ 1/8 & 1/2 & 1/8 \\ 0 & 1/8 & 0 \end{bmatrix}$ to filter the image noise. In particular, the image passes through the low pass filter for reducing noises.

After using the low pass filter, the filtered image needs to sharpen. It means that Enhancement of the image will be employed to make more prominent edges and the image is sharper for reducing the blurring effect after the low pass filter. This enhanced image allows to detect edges for improving the quality of the entire image. It means that edge detection will allows to find the location of brain tumor in the image.

In order to enhance the image, a high pass filter is employed, particularly a convolution operation between the source image and a 3-by-3 kernel $\begin{bmatrix} 0 & -1/4 & 0 \\ -1/4 & 2 & -1/4 \\ 0 & -1/4 & 0 \end{bmatrix}$ is used to sharpen the image.



(a) (b)

Figure 3*. Filtered and enhanced image: (a)_ filtered image & (b)_ Enhanced image.*

As the result in Fig. 3, the *enhanced* image is clear, and the tumor is more sharpened. Thus the following gradient transformation will be applied to create the image edge.

2.2 Gradient Transformation Approach

Depending on the survey summary table 2.1, the gray-level of the tumor is approximately between 107 and 159. Therefore, the pixels, which are not belong to the tumor, can be removed using the following equation, in which all of pixels, which have gray-level being not belong to the tumor, are set to 0.

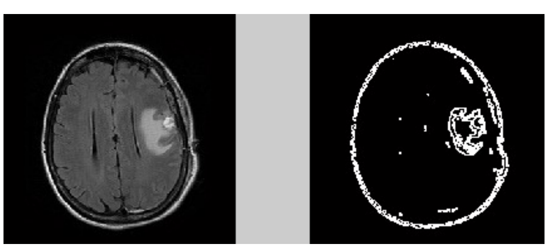
$$I'(x,y) = \begin{cases} I(x,y) & , Glev \notin [tmin; tmax] \\ 0 & , otherwise \end{cases} \quad (2.3)$$

where tmin, tmax are the gray-level values of each tumor image set with (tmin = 107, tmax = 159).

Table 2.1. The gray-level range of tumors corresponding to images

Number of images	tmin_gray	tmax_gray
1	111	152
5	113	161
8	101	164
12	100	157
19	109	149
27	110	170
35	101	162
Average	**107**	**159**

After removing pixels without meaning, the image is passed through the Sobel filter to transform into the gradient magnitude image, and the boundaries of the tumor are emphasized as shown in Fig. 4.



(a) (b)

Figure 4. *Gradient magnitude and enhanced images: (a)_ Enhanced image; (b)_ Gradient magnitude image.*

Fig. 4b is the result of using two uses two 3-by-3 kernel matrixes which are convoluted with the original image to calculate approximations of the derivatives, in which one for horizontal changes, and one for vertical. As the result, the horizontal and vertical edges are emphasized.

Suppose that the source image is defined as **A**, and $\mathbf{G}_x$ and $\mathbf{G}_y$ are two 3-by-3 kernels which are used to detect horizontal and vertical edges respectively, the Sobel kernel matrixes are described as follows:

$$G_x = \begin{bmatrix} 1 & 2 & 1 \\ 0 & 1 & 0 \\ -1 & -2 & -1 \end{bmatrix}, G_y = \begin{bmatrix} 1 & 0 & -1 \\ 2 & 0 & -2 \\ 1 & 0 & -1 \end{bmatrix} \quad (2.4)$$

where * denotes the 2-dimensional signal processing convolution operation.

The x-coordinate is the increasing from left-to-right direction, and the y-coordinate is the increasing from top-to-down direction. At each point in the image, the resulting gradient approximations are combined to obtain the gradient magnitude as follows:

$$G = \sqrt{G_x^2 + G_y^2} \quad (2.5)$$

2.3 Morphological Operation

Morphological Operation is the basic morphology operator based on the shape and structure of the image. The calculators applied a structural factor in the input image and the output image created with the same dimensions. Two main morphology operators are dilation and erosion [10], where the erosion makes the considered objects in the image thinner and the dilation makes the considered objects in the image thicker. In this proposed work, the dilation is the chosen method. This operation uses the highest value of all vicinity pixels determined by the structuring element. The operator is computed as follows:

$$g(x,y) = \sum_{i=1}^{M}\sum_{j=1}^{N} f(x,y)h(x-i,y-j) \tag{2.6}$$

where f(x,y), g(x,y) are the images before and after applying the morphological operator respectively. h(x,y) describes a diamond-style structuring element with R=3, as Fig. 5.

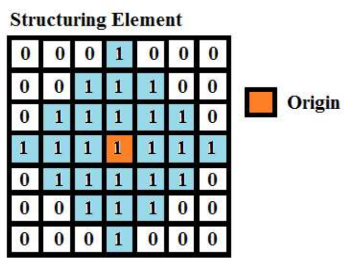


Figure 5. *Diamond-style structuring element with radius R=3.*

Fig. 5 is a structuring element used to connect the marginal dashed out before using the watershed transform to segment image. After executing the equation 2.6 between the source image and diamond-style structuring element, we get the result image as Fig. 6.

(a) (b)

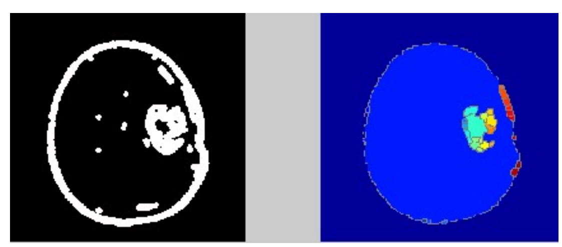
Figure 6*. Image after applying morphological operator (dilation) with (a)_ Image before applying dilation operator; (b)_ Image after applying dilation operator.*

As the result in Fig. 6b, all of dashed tumor boundaries are connected together and prepared for watershed transformation the image.

2.4 Watershed transformation

Watershed transformation is one of the methods to group pixels based on the basis of the image intensities. In particular, pixels having similar intensities are grouped together so that the image is partitioned into small and contiguous regions.

The watershed transformation algorithm defines two terms of catchments basin and dams. In particular, each catchment basin contains the lowest gray-level pixels and the dams were constructed to separate catchment basins. Moreover, the watershed map is as an intensity topographic, includes many separations of distinct basin, in which a drop of water is flown down towards distinct basins. Thus two contiguous basins are met, the dam between them is built up to prevent them from joining together. Finally, it results in the watershed transformation, includes many basins which are separated by watershed lines (dams).



(a) (b)

Figure *7. Watershed transformed image with (a)_ Image applied the dilation operator; (b)_ Image after watershed transformation.*

After converting into gradient magnitude image and applying the dilation operator, the boundaries of the tumors are detected and not discontinuous so that the image is transformed using watershed algorithm as shown Fig. 7b. In particular, the inside part of tumor, liked a basin, was filled up and each basin was marked with the same label. However, because of the over-segmented problem of the watershed transformation, the tumor is not only belong to one basin, but also some contiguous others.

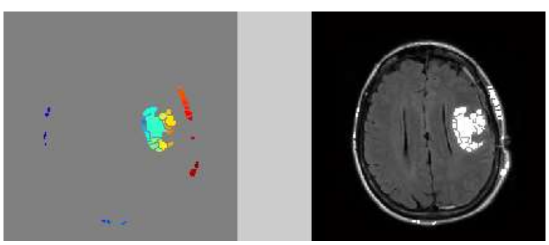
2.5 Tumor Region of Image

As shown in Fig. 8b, there are some big distinct regions (basins) which is not belongs to any tumor objects. The following equation is used to remove them and the result is shown in Fig. 8a.

$$W'(x,y) = \begin{cases} W(x,y) & , num_{pix} < max_{\ pix} \\ 0 & , otherwise \end{cases} \quad (2.7)$$

where W(x,y), W'(x,y) are the watershed transformed image before and after transforming, respectively. num_{pix} is the number of pixels in each distinct region.

After processing 50 images, max_{pix} is chosen about 5000. The pixels in unwanted regions are set to 0 and are become watershed lines. In Fig. 8a, each basin is marked with a label not to be zero and displayed with a different color. The result is that the tumor region is a group of contiguous basins because of the over-segmented problem.



(a) (b)

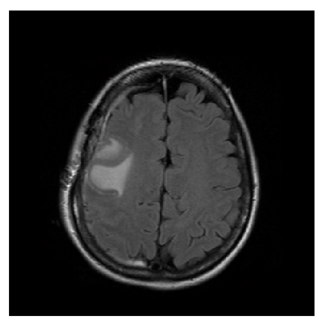
***Figure 8**. Tumor region image: (a)_ Watershed transformed image after removing unwanted region; (b)_ Image with the highlighted tumor region.*

Compiling the watershed transformed image after removing unwanted regions with source image, the tumor region image with highlighted tumor region is archived as shown in Fig. 8b.

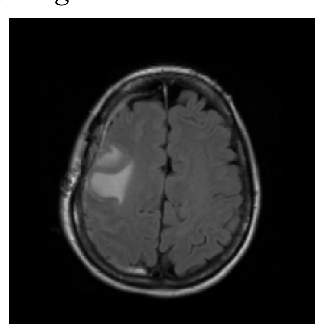
3. RESULTS AND DISCUSSIONS

The set of source images includes two types: the normal MRI images and the abnormal MRI tumor ones. In this paper, those are loaded into the tumor detection processing to determine the location of the tumor as shown in Fig. 9. Firstly, the brain image needs to preprocess to reduce noise using a low-pass filter as shown in Fig. 9b and then to enhance the sharp of tumor boundary using a high-pass filter, as Fig 9c.

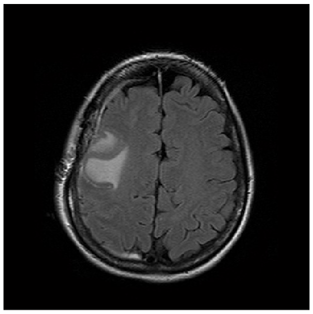
After that, the pixels, which have the gray-level outside the tumor range, will be removed from the image. In addition, the Sobel filter is applied to transform the source image into the gradient magnitude image for detection of boundary of the tumor as Fig. 9d. In Fig. 9e, the intermittent tumor boundary is interconnected with each other using the morphological-dilation operator. Moreover, the watershed transformation is utilized to fill up the tumor region with one or more contiguous labels.



***(a)** Original brain tumor image*

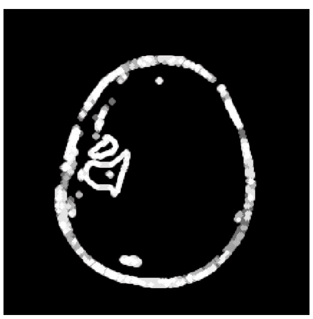


***(b)** Noise removed image*

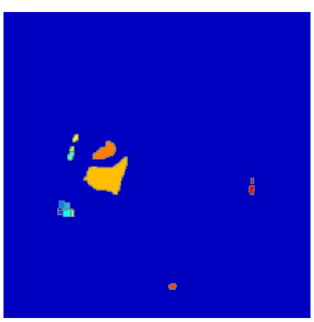


(c) *Image with sharped tumor boundary*

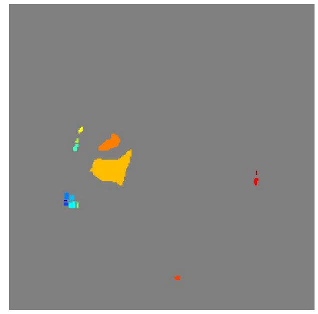
(d) *Gradient Transformed Image*



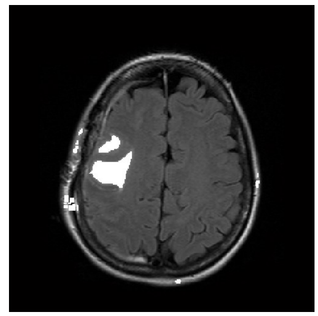
(e) *Image after applying dilation operator*



(f) *Watershed Transformed image*



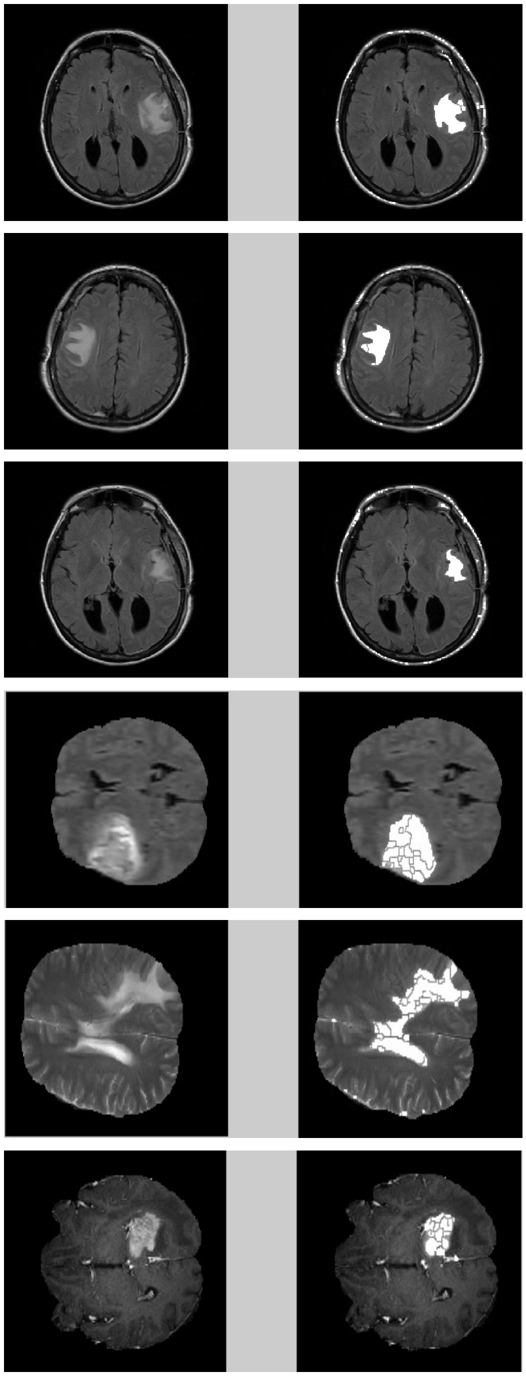
(g) *Watershed transformed image after removing unwanted regions.*



(h) *Output Image*

Figure 9. *Tumor detection processing*

After applying the watershed transformation, the image appeared some unwanted regions, so the proposed of equation (2.7) allowed to remove them, and the result is as shown in Fig. 9g. Finally, the result in Fig 9g and the source image were combined to produce the tumor region as in Fig. 9h.



(a) Source images *(b) Result images*

Figure 10. *Some of other images using to test the proposed tumor detection processing*

Fig. 10a (the left column) shows some other source images, which are processed by using the proposed method and the tumors were detected in the result images visually as shown in Fig.10b (the right column). The gray level of the tumors is updated to 255. So in the result images, the tumors are highlighted with white-color.

The location and shape of tumor are determined. But it does not exactly like the origin image. And depending on the condition when the MRI is taken, some normal parts of brain might have the characteristics similar to parts of tumor. In this case, the normal parts of brain can be confused with the tumor.

With this proposed method, the process to detect and segment the brain's tumor is fast and automatic. But in some case, it needs the doctor to check the confused parts again.

4. CONCLUSION

The use of computer science plays an important role in the analysis of various diseases and MRI image is an important part of many researchers. Therefore, this article presents the proposed method of brain tumors segmentation based on the combination of edge detection, morphological operator and watershed transformation. In addition, this method has been applied successfully on the MRI medical images. With this approach, we can segment tumor faster and reduce the user interaction. As the result, the proposed processing method can extract the region of brain tumors, which can allow develop an automated system for determination of the tumors more exactly. Furthermore, the method can be improved for more demanding tasks, such as liver, heart or kidney segmentation with the 3D CT scanner and MRI images.

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