Comparison of brain tumor segmentation methods based on different algorithms using MRI images

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Abstract. Brain tumor is a serious disease for human beings. MRI is the most widely used method for its innocuousness since people do not need to be exposure to radioactivity. The segmentation on MRI images is a vital step in tumor detection. To improve efficiency and accuracy of the segmentation, scientists apply different algorithms in this process. This paper focuses on three particular algorithms including Connected component label algorithm (CCLA), Watershed algorithm (WSA) and Fuzzy C-means clustering algorithm (FCCA). The principles and applied procedures of these three algorithms are introduced. Basing on this background information, algorithms are compared from three aspects. Fuzzy C-means clustering algorithm is considered as more efficient and accurate among these three algorithms. All algorithms have good research prospects, and the segmentation result can be improved through the improvement on algorithms.

Keywords: connected component label algorithm, watershed algorithm, Fuzzy C-means (FCM) clustering algorithm, brain tumor segmentation, MRI images.

1. Introduction

Brain tumor is a new growth in the brain that caused by local histiocytic hyperplasia [1]. Considered the significance and complexity of brain tissues, the treatment of brain tumor is a major medical challenge. To further determine the tumor status, Magnetic resonance imaging (MRI) is the most common and best choice for doctors [2]. Depending on the principle that nucleus can have transitions between orbits under the effect of the magnetic field, MRI can provide the details of people internal organs. It is regularly chosen for its accuracy and less harm for human body [3]. However, the grey scale difference between the tumor part and regular part is not so obvious. So, image segmentation is needed.

MRI Images segmentation is the crucial next step for separating the diseased brain tissue area from other parts. This process contributes to construing a well-developed and individualized medical treatment. In the past, the segmentation was done by specialists which consumed considerable time to achieve accuracy. The great differences in the shape and texture between individuals also contribute to the complexity of the process [2]. To improve efficiency, researchers nowadays are trying to use computer to accomplish this work, however, the individual difference in the images remain as a huge challenge. Combined with original data provided by qualified clinicians, specialists are using various algorithms to train the accuracy of computer programs [2].

In this paper, brain tumor segmentation methods basing on three different algorithms are studied. Watershed algorithm, Fuzzy C-means clustering algorithm and Connected component label algorithm are introduced and followed by the comparison analysis.

2. Methods

2.1. Images Segmentation

Images segmentation is a process that using different algorithms to divide images into different parts with unique individual characteristic. It is the key step from image processing to image analysis. Depending on the grey scale, color, texture and structure, one image is separated into different non-overlapping areas. Magnifying the similarity in one area while the differences between distinct areas which contribute to the improvement of quality and clarity of images [4]. Generally, there are four kinds of image segmentation methods including basing on threshold value, area, margin and specific theory [4]. In this paper, only three classical algorithms which are widely used are chosen to analyze basing on their characteristics.

2.2. Algorithms

2.2.1. Watershed Algorithm. Watershed algorithm separates objects in the image by imitating geographical structure. For this algorithm, the grey scale image of the original image can be seen as a topographic map. The area with high grey scale can be seen as peak while the area with low grey scale can be seen as valley [5]. If valleys are flooded with water in different colors and dams are built in peaks to separate different areas in case of water mixing. When all peaks are submerged, image segmentation is achieved.

In brain tumor segmentation, watershed algorithm is applied for the separation of gray matter, white matter, and cerebrospinal fluid in MRI images [3]. The first step of the segmentation using watershed algorithm is to process the input image by gradient. Using morphological operation to erase some small minimums in case of over-segmented [3]. Then classify the pixel points basing on the grey scale of the input image and then set the threshold value: n. Find pixel points with the lowest grey scale and set them as the initial points. The plane of these points is regarded as the initial plane. Raise the plane from the initial to the plane of points with the highest grey scale. During the rising, the plane will cover other pixel points. Calculate the difference of the grey scale between the covered point and initial point. If the difference is smaller than the threshold value n, then the covered point is marked with black [3]. Otherwise, the point is marked as white. In this case, the white points classify the whole pixel image and segmentation is achieved.

2.2.2. Fuzzy C-means (FCM) clustering algorithm. FCM algorithm is one of the most widely used and successful algorithms among all clustering algorithms. It optimizes the objective function to get the degree of membership function of all sample points to all class centers, then decide the genus of all sample points to achieve classification. There are three important concepts in this algorithm:

(1) Objective function. Objective function is the sum of Euclidean distances from points to classes in essence as shown in Equation (1), in other words, sum of squares of error. The clustering of the algorithm is the process of minimizing objective function. Through iteration, the ultimate clustering result got by decreasing error of objective function.

$$J_m = \sum_{i=1}^{N} \sum_{j=1}^{C} u_{ij}^m \|x_i - c_j\|^2, \quad 1 \le m < \infty \tag{1}$$

Here, m represents the number of clusters; N represents the number of sample points; C represents the number of clustering centers; Cj represents the jth cluster center; xi represents the ith sample point; uij represents the degree of membership function of xi to cj.

(2) Matrix of degree of membership function Uij. The matrix contains the degree of each point belonging to each clustering center. For every sample point, the sum of degree of membership function

to all clustering center is equal to 1. The degree of membership function to one clustering center is higher when it is closer to 1. The point will belong to one clustering point of whose degree of membership function is the highest.

(3) End condition. The condition is shown as formula (2).

$$max_{ij}\left\{\left|u_{ij}^{(t+1)} - u_{ij}^{(t)}\right|\right\} < \varepsilon \tag{2}$$

ε is the error threshold value which is a really small number. The iteration will stop when the biggest difference between two generation of iteration less than the error threshold value.

The process of the algorithm is that: (1) Choose propriate C and m. Initialize U0; (2) Calculate cj according to the objective function; (3) Calculate uij and get the new matrix Uj; (4) Compare Uj and last matrix, if the value less than error threshold value, then stop iteration. Otherwise, come back to step 2.

FCM algorithm is especially suitable for the brain tumor segmentation for its advantages of easily achievement and mature theory basis. When it applied in MRI image segmentation, the sample points are pixel points of the images [6].

2.2.3. Connected component label algorithm. Connected component label algorithm is one of the most popular algorithms in image segmentation. It is actually a process of scanning all pixel points in images. For points with the same pixel value, they are regarded as a group. Doing the scanning until all pixel points are grouped. The algorithm is processed by checking neighborhood 4 pixel of the main pixel. If a pixel point adjacent to its left pixel, right pixel, above pixel and below pixel, then it is called neighborhood pixel 4(N4) [8]. The image is scanned from above to below and from left to right.

The procedure is as follows:

(1) The MRI image with grey scale is inputted. Determined the threshold value. For all pixel points, compare the grey scale with the threshold value. If the grey scale is smaller, reassign 0 to the point. Otherwise, reassign 1 to the point.

(2) Checking the N4 of each pixel point. If the value is 1, then the point is adjacent and is labeled. If the value is 0, then ignore this point.

(3) Move on to the next neighboring pixel point. Repeat operation 2.

(4) Stop scanning until all pixel points are checked.

On this basis, brain tumor objects are successfully determined, and segmentation is achieved.

3. Comparison

3.1. Evaluation

3.1.1. Accuracy. For WSA, assigning different value to different parts and labeling them with different colors help to guarantee the accuracy of images with strong edge contrast [5]. Adopting morphological operation contributes to better segmentation result. What's more, WSA combines the frontier approach and the region approach which means a more efficient detection of frontier and region of images. For CCLA, in consideration of comprehensive scanning, most results of segmentation accord with the exact image [8]. For FCCA, it uses iteration to get the best degree of membership function which means a flexible fuzzy partition. This can lead to a more accurate segmentation than hard partition.

For used images, though they are all MRI images, all these three algorithms will reprocess them and before going to next step. For WSA and CCLA, the images actually used are binary images, but for FCCA, the degree of membership function can be values between 0 and 1 [9]. It can conclude that the group classification for FCCA is more accurate which leads to better result of brain tumor segmentation.

3.1.2. Deficiency and solution. The gradient operation used in process of WSA may lead to over-segmentation caused by images without strong edge contrast and shadow. There are other watershed algorithm basing on labeling can solve above problems [5]. Effort has been put on solving the over-

segmentation and further research can be down on applying improved algorithms to brain tumor segmentation.

The threshold value chosen for WSA and FCCA is really important. If error threshold value determined for FCCA is not propriate, poor segmentation effect will be got. The deciding process can be complex and challenge, but repeated learning of the algorithm can help to get the suitable value. What's more, there are other variants forms of FCCA that avoid choosing a threshold value. In this case, extra effort spend on decision can be saved and there is no risk of getting poor results. Unsuitable threshold value of WSA can lead to over-segmentation which makes it the key factor of the process. Different from FCCA, all other variant forms of WSA need this value but there are a number of approaches that have been studied efficient to get a proper value.

The FCCA itself has a problem that it is sensitive to the original clustering center number. And this may lead to the instability of the segmentation [10]. But a fast global FCCA that have been studied as efficient can help to solve the problem [7]. It does not depend on any initial conditions but globally search the image to achieve clustering.

3.2. Result

Depending on the accuracy and deficiency of three algorithms discussed above, FCCA can be the better choice among all. It has a high accuracy compared to WSA and CCLA both on used images and working procedure. There are problems remained in all three algorithms, but variant forms can help to solve the problem. CCLA and WSA cost more time compared to FCCA since these two algorithms all need checking all pixel points of the image. However, clustering process of FCCA can get accurate result and save time at the same time.

4. Conclusion

In this paper, brain tumor segmentation through Connected component label algorithm, Watershed algorithm and Fuzzy C-means clustering algorithm are introduced. The basic background knowledge is introduced and the applications of algorithms in brain tumor segmentation are explained on this basis. To make comparison, accuracy, and deficiency, two of the most important evaluation criteria in image segmentation, of all algorithms are introduced. Fuzzy C-means clustering algorithm is better than other two algorithms on its higher accuracy and lower time cost that caused by clustering.

In the future research, more attention can be paid to improve the algorithms of existing brain tumor segmentation methods. In addition, new algorithms that can be applied in segmentation with better efficiency and accuracy to further the study.

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