Magnetic Resonance Brain Image Segmentation and Reconstruction Technique Based on Genetic Fuzzy Clustering Technique

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***Abstract* - Medical image segmentation is a classic difficult problem in medical image processing. Image segmentation based on clustering technology is widely applied in medical image segmentation. Based on detailed analysis using fuzzy clustering technology for Magnetic Resonance, MR, brain image segmentation, the paper proposes a method combining automatic threshold, genetic algorithm and fuzzy clustering algorithm. The experimental results show that the segmentation quality and speed is higher than that of single rapid fuzzy cluster. This solves the problem of the present fuzzy cluster that initial clustering centre and initial membership matrix are difficult to determine and algorithm iteration is easy to avoid local extremes.**

Keywords - MRI, image segmentation, threshold, genetic algorithm, fuzzy clustering

I. INTRODUCTION

With rapid development of computer technology and electronic technology, based on magnetic resonance spectroscopy, MRI technique appears as a new imaging examination technology. With the help of RF pulsed excitation, it uses the inherent features of proton of hydrogen nucleus in magnetic field to make hydrogen atom release magnetic resonance signal by the migration of potential energy, and the gradient magnetic field is used to mark the spatial position of resonance hydrogen atom to achieve chemical information image of human tissue. MRI can provide great information, and has no radioactive damage for human body, so it is widely applied to diagnose system disorders, and it becomes a new medical imaging diagnosis technique.

MRI has the unique characteristics that it has no electromagnetic radiation damage and has no bony artefact, and it can provide higher soft tissue resolution, which makes it become the best method to examine brain disorders. Three-dimensional structure of brain can improve the accuracy of medical diagnosis, and it has great application value for clinical diagnosis, brain surgical plan and simulation, treatment planning formulation, anatomy education and medical research. But MRI only provides two-dimensional slice images of brain. To achieve three-dimensional structure of brain, it needs to use three-dimensional reconstruction of image based on two-dimensional image, and segmenting two-dimensional magnetic resonance brain image is a key step to realize three-dimensional reconstruction of brain. In addition, accurate segmentation on two-dimensional magnetic resonance brain image is an important basis to realize quantitative measurement of brain. And the change of brain tissue plays an important role in researching brain diseases. For example, in the researches of senile dementia, multiple sclerosis and schizophrenia, besides researching spatial position of grey matter, white matter and cerebrospinal fluid, it is necessary to measure geometry parameters of the brain tissues.

Based on the above analysis, we can see that it has great realistic significance to achieve the image segmentation method for the characteristics of magnetic resonance images and realize accurate segmentation of magnetic resonance images. If it can solve the segmentation problem of magnetic resonance images, it has great promotion for the development of medical imaging.

II. GENETIC FUZZY CLUSTERING ALGORITHM RESEARCH

A. Introduction of Genetic Fuzzy Clustering Algorithm

Fuzzy clustering algorithm is a local optimization algorithm. It has the disadvantages that it is sensitive to initial clustering centre and it is easy to be local extreme, the reason for which is that initial clustering centre is close to local extreme. Genetic fuzzy clustering algorithm is an integration algorithm combining genetic algorithm and fuzzy clustering algorithm. Firstly, the advantage of global optimization of genetic algorithm is used to cluster centre which is close to global optimization. Then, the advantage of local optimization of fuzzy clustering is used to make the final classification result in the global optimization. Compared with single fuzzy clustering

algorithm, genetic fuzzy cluster has the following advantages.

(1) It solves the problems of fuzzy clustering algorithm that the initial clustering centre or membership matrix is difficult to be determined. The paper combines genetic algorithm and clustering algorithm, and uses the objective function of hard clustering as the global optimization condition of genetic algorithm to find the better initial clustering centre which is better than single hard clustering algorithm, and the arithmetic speed is fast.

(2) It solves the problem of local extreme. The paper uses genetic algorithm to determine initial clustering centre of fuzzy clustering. Genetic algorithm is a global optimization algorithm, and the achieved hard segmentation is nearly the best hard segmentation result, so the class centre is close to the optimal solution, which reduces the possibility that fuzzy clustering is local extreme.

B. Genetic Fuzzy Clustering Algorithm in the Paper

The implementation process of genetic fuzzy clustering algorithm in the paper is as follows. Firstly, K-means clustering objective function is used as fitness function to implement genetic algorithm and find the optimal individual of hard segmentation, and the class centre is solved. Then, the class centre is used as initial clustering centre of fuzzy clustering, and only a fuzzy clustering iteration is used to solve the membership of each grey value. Lastly, according to the membership, the final classification result is determined by threshold, which means the determination of segmentation results. There are many literature proposing medical image segmentation based on genetic fuzzy clustering. For example, literature [1-3] proposes genetic fuzzy clustering algorithm or improvement algorithm in order. Compared with the literature, the improvement of the algorithm in the paper is as follows.

(1) It selects cluster numbers which are different from the literature, which not only improves the accuracy of segmentation results, but also improves the speed of fuzzy clustering.

(2)The encoding mode which is different from that of the literature is used in genetic algorithm, which not only makes it is easy to migrate individual genes, but also makes it closer to actual condition of image segmentation, and the segmentation results are accurate.

(3) The determination mode of classification results is different from the literature, which not only reduces segmentation accuracy of cerebral white matter, but also improves segmentation accuracy of grey matter and cerebrospinal fluid.

III. APPLICATION OF GENETIC FUZZY CLUSTERING TO MR BRAIN IMAGE SEGMENTATION

The scheme in the paper includes pre-processing of MR brain image and accurate segment of brain tissue images, and the processing flow of images is shown in Figure 3. Firstly, for the original images, automatic threshold segmentation method is used for image processing to extract brain tissues. Then, for the brain tissue images, the genetic fuzzy clustering algorithm in the paper is used for image segmentation. Finally, cerebrospinal fluid, grey matter and white matter is achieved. The paper analyses and discusses the parameters of the algorithm in the paper. And the paper focuses on analysing the influence of pre-setting four parameters (cluster size, evolving algebra, crossover probability and mutation probability) on genetic algorithm.

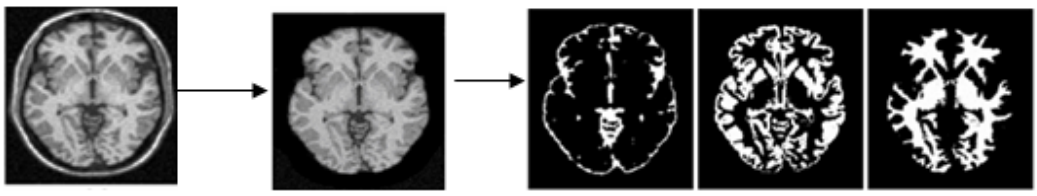

Figure 3 MR brain image segmentation flow

A. Analysis and Discussion on Genetic Algorithm in the Paper (Brain Web)

The paper selects the following images as experimental objects. (1) 17 cross sectional bit images in Brain Web, TR/TE/FA=18ms/10ms/30°, the pixel size is 1mm×1mm and the image size is 217×181. (2) 20 coronal images in IBSR annotated corpora, TR/TE/FA=50ms/9ms/50°, the thickness of layer is 3mm and the image size is 256×256.

The paper and literature [1-3] use genetic algorithm to determine the initial class centre of fuzzy clustering, but the genetic algorithm of the paper has evident difference from the literature.

Firstly, the paper marks the class of grey value as genes for coding. Compared with the literature which uses class centre as coding mode of genes, it is more suitable for the essence of image segmentation, and the coding and encoding process of individuals is easy and direct.

Secondly, the coding scheme in the paper is easy to implement mutation. Using class centre as the gene is difficult t o determine step value of variation, but the coding scheme in the paper is easy for variation. And the variation in the paper is closer to real situation of image segmentation. Compared with the literature, it is more direct and more accurate.

Table 1 shows the fitness function values of the optimal hard segmentation from Literature [1-3] and genetic algorithm in the paper. From Table 1, we can see that the image segmentation quality of the genetic algorithm in the paper is better than that in literature [1-3].

TABLE 1 FITNESS FUNCTION VALUES OF THE OPTIMAL HARD SEGMENTATION FROM TWO GENETIC ALGORITHMS

Image number (Ch2bet)	024	032	040	048	056
The paper	2.27888	7.76086	9.68359	15.6113	15.2116
Literature [1-3]	2.30140	7.76286	9.70129	15.6506	15.2237
Image number (Ch2bet)	064	072	080	088	096
The paper	15.5699	17.3089	19.3404	16.5937	16.2443
Literature[1-3]	15.6613	17.3538	19.3714	16.6167	16.2629

B. Optimization of Parameters of Genetic Fuzzy Clustering Algorithm in the Paper (Brainweb)

The research objects in the paper are brain images of the normal. From medical priori knowledge, we can know that segmenting brain tissues of images can directly determine cluster number. Brain tissues include white matter of brain, grey matter of brain and cerebration fluid, so the cluster number is 3. How to select the optimal fuzzy weighting index is shown in literature [4], as follows. Under the condition of using fuzzy clustering algorithm to process medical images, it is rational t hat the range of selecting fuzzy weighting index is from 1.5 to 3.6. And when the selected fuzzy weighting index is close to 2, it is close to the optimal, so the selected fuzzy weighting index in the paper is 2. How to determine the initial clustering centre and the influence of the parameter on fuzzy clustering algorithm has been introduced in the above chapter. For the selecting of distance parameter, the experiment only uses single feature information, grey information of images, so using simple Euclidean distance can express the difference between different grey values.

The parameters in genetic fuzzy clustering algorithm influencing image segmentation include four parameters of genetic algorithm. The next chapter mainly analyses the quality, speed and stability of four parameters on brain image segmentation. The stability of genetic algorithm is low, the fitness value of the genetic algorithm is the means after 20 tests. (Note: (1) the fitness function in the paper is objective function of K-means cluster, so the smaller the fitness in the table, the higher the fitness. (2) Under the condition that other parameters is invariant, the experiment tests the influence of a parameter on image segmentation.

B1. Influence of Population Size on Image Segmentation of Brain Tissues

Individuals composing populations generate randomly. The number of individuals in groups can be changed randomly, so the stability of segmentation results is worse, which makes the influence of population size on image segmentation is not evident. Therefore, for the comparison of the part, the paper uses the mode of randomly increasing individuals to change the size of populations based on the original populations, and the experimental results are shown in Table 2. Figure 5 shows the influence tendency of population size on brain tissue image segmentation according to the data in Table 2.

TABLE 2 RELATIONSHIP BETWEEN POPULATION SIZE AND FITNESS VALUE OF THE OPTIMAL INDIVIDUAL

Population size	20	30	40	50	60
Fitness of the optimal individual	16.5522	16.4935	16.4798	16.4793	16.4798
Population size	70	80	90	100	110
Fitness of the optimal individual	16.4792	16.4793	16.4792	16.4792	16.4792

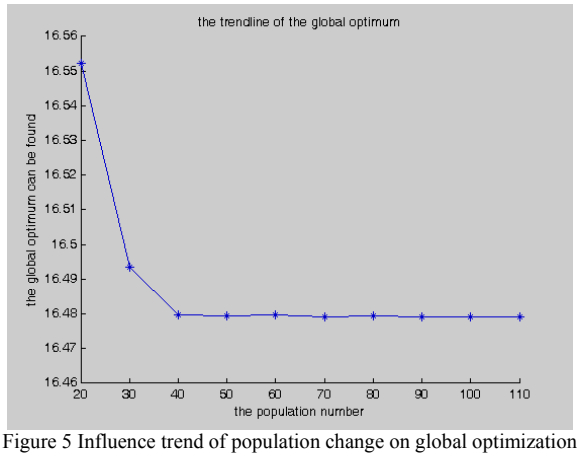

Figure 5 Influence trend of population change on global optimization capability

From genetic algorithm, we can get that the greater the population, the diversity of individuals' increases, and the possibility of the optimum increases greatly. With the increase of populations, the calculation of genetic algorithm increases, which reduces the efficiency of the algorithm. Therefore, with the increase of populations, the fitness value of the optimal individuals has no evident change, the population size should be the front side of the stable trend. For the stability, the greater the population is, the more stable the segmentation result is.

B2. Influence of Evolving Algebra on Image Segmentation of Brain Tissues

There are two common methods determining termination conditions of genetic algorithm, (1) Determining evolving algebra to be implemented, (2) Determining the conditions required by the optimal individuals. It is difficult to determine the conditions required by the optimal individuals, so the paper selects the first method, determining evolving algebra of genetic algorithm. Then, the individual with the highest fitness is selected from the last generation of population individuals as the segmentation result. From the theory of genetic algorithm, we can know that with the increase of evolving algebra, the possibility of finding the optimal individual increases, but the operation time increases. Therefore, with the increase of the evolving algebra, the fitness value of the optimal individual has no evident change and tends to be stable, the evolving algebra should be the front side of the stable trend,. And figure 6 is the influence trend of evolving algebra on image segmentation of brain tissues.

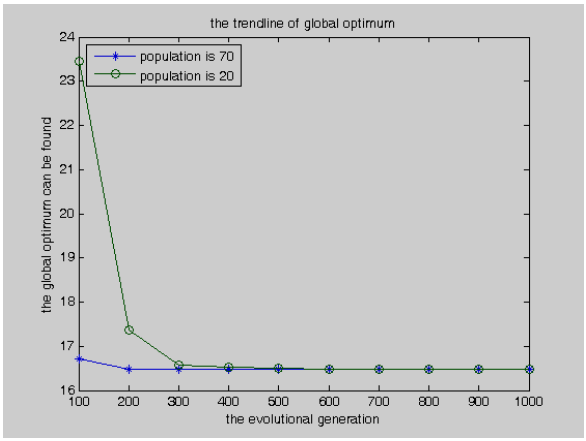

Figure 6 Influence trend of crossover probability on image segmentation of brain tissues

B3. Influence of Crossover Probability on Image Segmentation of Brain Tissues

Crossover not only is the most important operation in genetic algorithm, but also derives excellent individuals continuously, and keeps diversity of individuals, which makes genetic algorithm not converge rapidly and not easy to be local extreme like fuzzy clustering algorithm. Therefore, crossover is necessary. It plays an important role in the early stage of genetic algorithm. However, if all individuals in population make crossover, which means that the crossover probability is 1, while the diversity of individuals increases, the population doesn't converge any more, the reason for which is that selecting excellent genes may be damaged, which makes the evolutionary process irregular. And the disorder must make the operation difficult to be converged, which reduces the operation efficiency of genetic algorithm. Figure 7 is the influence trend of crossover probability on segmentation quality according to the data.

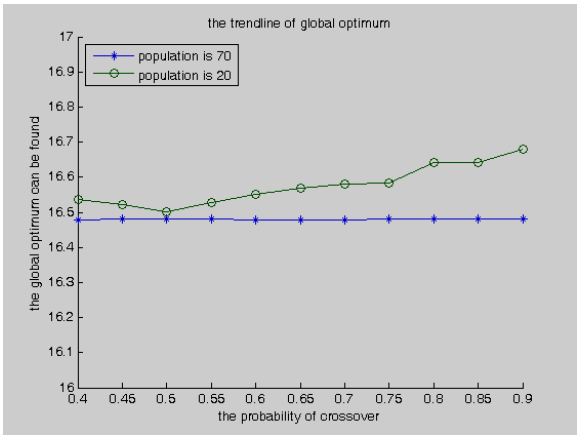

Figure 7 Influence trend of crossover probability change on global optimization ability

From Figure 7, we can get the following conclusion. When the population number is small, the influence of crossover probability on global optimization ability of algorithm is greater. When the population number is great, the influence of crossover probability on global optimization ability is smaller. The reason is that when population number is small, the diversity of individuals in population is less. In the early stage of genetic evolution, crossover becomes the main source of increasing diversity of population, and the diversity of population determines

0.4 and 0.5, crossover plays the role of increasing diversity of population and improving optimization ability. When the crossover probability is greater than 0.5, crossover damages excellent individuals in population, which makes optimization ability of algorithm reduce.

B4. Influence of Mutation Probability on Image Segmentation of Brain Tissues

Mutation means gene mutation when the individuals derive. So the mutation probability should not be great. Too great mutation probability makes excellent genes be damaged, which makes the process evolve towards uncertain direction, and causes the algorithm not converge. When excellent individuals are evident, which means that the individuals nearly fill the population, mutation operation is used to keep diversity of individuals and control convergence speed of algorithm. So the mutation probability should not be 0. If the mutation probability is 0, it makes the convergence speed too fast and is easy to be local extreme, which reduces segmentation quality of the algorithm. Figure 8 is influence trend of mutation probability on segmentation quality.

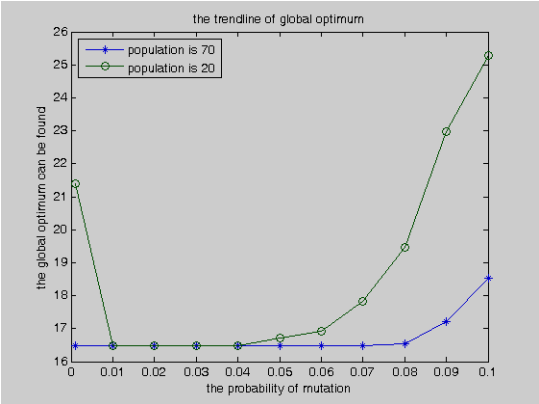

Figure 8 Influence trend of mutation probability on global optimization ability

From Figure 8, we can get the following conclusions. When population number is small, the influence of mutation probability on global optimization ability of the algorithm is great. When the global optimization ability is great, the influence of mutation probability on global optimization ability of the algorithm. Therefore, when population number is small, the influence of crossover probability on global optimization ability is greater. In addition, from Figure 7, we can get that when crossover probability is between 0.4 and 0.5, with the increase of crossover probability, the global optimization ability increases. When the crossover probability is greater than 0.5, with the increase of crossover probability, the global optimization ability reduces, which means that when the crossover probability is between optimization ability of the algorithm is little. The reason is that when the population number is small, the diversity of individuals in population is less. In the later stage of genetic evolution, crossover becomes the main source of increasing diversity of population, and the diversity of population determines global optimization ability of the algorithm. Therefore, when population number is small, the influence of crossover probability on global optimization ability is greater. In addition, when mutation probability is between 0 and 0.01, with the increase of crossover probability, the global optimization ability increases. When the mutation probability is greater than 0.04, with the increase of mutation probability, the global optimization ability reduces, which means that when the crossover probability is between 0 and 0.01, mutation plays the role of increasing diversity of population and improving optimization ability. When the crossover probability is greater than 0.04, mutation damages excellent individuals in population, which makes optimization ability of algorithm reduce.

From the above analysis, we can know that for population size, evolving algebra, crossover probability and mutation probability, the influence of population size on segmentation quality of images is the greatest. When population is great, the influence of evolving algebra, crossover probability and mutation probability on image segmentation quality is little.

In genetic algorithm, the selection of coding mode, length of coding, and selection of operator, crossover operator and mutation operator influences the final results of the algorithm, In addition, only predetermining three genetic algorithms can make the research on optimal selection of population size, evolving algebra, crossover probability and mutation probability has great significance. In other words, applying different selection operators to compare the influence of population size on genetic algorithm, applying different crossover operators to compare the influence of crossover probability on genetic algorithm, and using different mutation operators to compare the influence of mutation probability on genetic algorithm is not comparable. The comparative analysis is complicated. In view of complicity of algorithm, operation speed, and quality and stability of image segmentation, theoretically, it is impossible to find a compound mode which not only meet the above factors, but also achieves the optimal.

IV. CONCLUSIONS

The paper tests the quality of image segmentation based on genetic fuzzy clustering technique, and makes detailed analysis and discussion. The experiment of image segmentation fully indicates the segmentation quality of the segmentation method in the paper is good. The paper deeply analyses and researches the status and existing problems of image segmentation method based on fuzzy cluster. For the problems of image segmentation method based on fuzzy cluster that effective initial clustering centre or initial membership matrix is difficult to be determined and is easy to be local extreme, the paper makes deep research and exploration, and proposes the solution.

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