Research on Image Segmentation Method Based on Fuzzy Clustering

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Abstract: Image segmentation is to divide an image into several continuous non-overlapping regions with similar characteristics, such as gray level, color and texture information. Through image segmentation, we can extract specific objects from complex background. The image has great uncertainty and fuzziness. Traditional segmentation methods often fail to achieve ideal segmentation effect, which directly affects the subsequent target feature extraction and result analysis. However, the fuzzy theory can well describe the characteristics of the image. Therefore, more and more scholars have studied image segmentation and proposed various related segmentation methods. Firstly, this paper analyses the hierarchical structure of image engineering. Then, this paper analyses the basic concepts of the fuzzy clustering algorithm. Finally, this paper analyses the image segmentation effect of the fuzzy algorithm by experiments.

1. Introduction
With the continuous progress and development of society, people are dealing with different kinds of information every day. These information are processed accordingly, 80% of which are image information obtained through vision. As the visual basis of human perception, image is an important medium for information acquisition, communication and transmission. With the rapid development of computer technology, people rely more and more on digital images. At the same time, more and more people process and analyze the acquired image information through computer technology. Therefore, the research of image processing methods based on fuzzy clustering algorithm has attracted more and more scholars'attention.

2. The hierarchical structure of image engineering
Image engineering is a new subject for the research and application of the whole image field. According to different degrees of abstraction and research methods, it can be divided into three important steps: image processing, image analysis and image understanding. Its hierarchical structure is shown in Figure 1. Image processing is a technology for analyzing and processing digital images. It is a low-level processing of image engineering. It generally includes image denoising, image enhancement, image coding, image restoration, etc. Image processing is a feature that satisfies human visual psychology through images. Image analysis is a process of separating and extracting the features of the target area and describing the measurement. Image analysis is the middle-level processing in image engineering. It is the transition from image processing to image understanding. Image understanding is located in the high level of image engineering. Based on image analysis, the characteristics, properties and relationships of target areas are analyzed. In this way, we can understand image information more regularly, so as to guide and plan action.
3. The basic concepts of the fuzzy clustering algorithm

3.1 Cluster Analysis
Clustering is a process of distinguishing and classifying things according to certain rules and requirements. In this process, there is no prior knowledge about category, but relying on the similarity between things as the criterion of classification. Therefore, the samples in each class are similar, and the differences between samples in different classes are large. So far, there are many kinds of clustering algorithms, usually divided into five types, including partition-based clustering algorithm, hierarchical clustering algorithm, grid-based clustering algorithm, density-based clustering algorithm and model-based clustering algorithm. The specific classification is shown in Figure 2.

3.2 Fuzzy Clustering Method
Fuzzy C-means (FCM) is a kind of fuzzy clustering method proposed by Bezdek. It calculates the membership degree of each sample belonging to each cluster by using the minimum square error sum as the clustering criterion. By iteratively optimizing the objective function of similarity between each sample and class C centers, we can obtain local minima and get the optimal clustering. The algorithm has good convergence and the result is not affected by the initial value. It has been widely used in image segmentation, compression, recognition and other fields. However, the objective function has many local minimum points, and the iteration of the algorithm is along the direction of the objective function reduction, which often leads to the convergence of the algorithm to the local minimum.

Given Data Set \( X = \{x_j, j = 1, 2, \ldots, N \mid X_j \in \mathbb{R}^q \} \), which represents vectors with \( N \) pixel images and is classified into \( C \) categories. Each component of vector \( x_j \) represents the feature of the image in its position, and \( q \) is the dimension of the feature vector.

FCM clustering algorithm is based on minimizing the following objective functions such as formula 1.

\[
J_m = \sum_{i=1}^{C} \sum_{j=1}^{N} u_{ij}^m D_{ij} \quad (1)
\]
In the formula: $u_{ij}$ denotes the membership function of $x_j$ of the first cluster, and $M$ is a power exponent (usually set to $m = 2$).

$$D_{ij} = d^2(x_j, v_i)$$ is the similarity measure of cluster centers $v_i$ and $x_j$ of class $i$. The most commonly used similarity measure is Euclidean square distance. The most commonly used similarity measure is Euclidean square distance, which is as follows the Formula 2.

$$D_{ij} = d^2(x_j, v_i) = \|x_j - v_i\|^2$$ (2)

The constraints of minimizing the objective function are as follows the Formula 3.

$$u_{ij} \in [0, 1], \sum_{j=1}^{C} u_{ij} = 1 \forall j$$

and

$$0 < \sum_{j=1}^{C} u_{ij} < N \forall i$$ (3)

Pixels far from the cluster center are given low membership values, while those near the cluster center are given high membership values.

Considering the constraints $u_{ij}$ of formula (3), we improve $j_m$ for the first time to make $u_{ij}$ and $v_i$ zero, and then we get two conditions for minimizing $j_m$, such as formula 4 and formula 5.

$$u_{ij} = \left\{ \sum_{k=1}^{C} \left( \frac{D_{ij}}{D_{kj}} \right)^{\frac{1}{m-1}} \right\}$$ (4)

$$v_i = \frac{\sum_{j=1}^{N} u_{ij}^m x_j}{\sum_{j=1}^{N} u_{ij}^m}, (i = 1, 2, \ldots, C)$$ (4)

The FCM algorithm optimizes iteration $j_m$ through formulas (4) and (5) until formula 6 is satisfied.

$$\max_{x_i \in [1, C]} \|y_i^{(t)} - y_i^{(i+1)}\|_{\infty} < \varepsilon$$ (5)

$L$ is the iteration index, $\|\cdot\|_{\infty}$ is the $L_\infty$ standard. After obtaining the membership value $u_{ij}$ of the jth pixel of the class i, the fuzzy clustering can set the pixel to the class with the highest membership value.

The $\{H_k\}_{k=1}^{C}$ is deblurred to $\{H_k\}_{k=1}^{C}$.

$$\max_{i \in [1, C]} (u_{ij}) = u_{kj} \Rightarrow x_j \in H_k$$ (6)

4. Experimental results of image segmentation

Simple genetic algorithm and traditional FCM algorithm are used to segment the original image Lena (gray level image, pixel 256 x 256). The experimental results and analysis are shown in Figure 3.
5. Conclusions
Fuzzy theory can well describe the characteristics of images. Therefore, more and more scholars apply the fuzzy theory in the research of image segmentation, and put forward many segmentation methods. Among them, the method based on fuzzy clustering has been widely used in the field of image segmentation, such as the fuzzy C-means (FCM) clustering method.

Acknowledgement
1. Cooperative Scientific Research Project of the "Chunhui Plan" of the Ministry of Education in 2017” Research on Image Segmentation algorithm of the Regon Thang-ga” (Project No.: Z2017048).
2. Undergraduate Teaching and Research Project of Qinghai University for nationalities 2017-2018” Research on Ways for Training Practical Ability of Students majoring in Information Management and Information System “(Project No.: 2017 - BK JXYB - 08).

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