Segmentation of Lip Images by Modified Fuzzy C-means Clustering Algorithm

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Abstract
In this paper, we describe the application of a modified fuzzy C-means clustering algorithm to the lip segmentation problem. The modified fuzzy C-means algorithm is able to take the initial membership function from the spatially connected neighboring pixels. Successful segmentation of lip images is possible with the proposed one. Comparative study of this proposed modified fuzzy C-means is done with the traditional fuzzy C-means algorithm by using Pratt's Figure of Merit. Experimental results using proposed method demonstrate encouraging performance.
Key words:
lip segmentation, local spatial interactions, Fuzzy clustering.

1. Introduction

Image segmentation is an important but still open problem in image processing. In this paper we propose a method for this problem by introducing spatial connectivity while selecting the initial membership function. Lip segmentation is an essential stage in many multimedia systems such as video conferencing, lip reading etc.
Our world is fuzzy, and so are images. Fuzziness Quantifies vagueness and ambiguity, as opposed to crisp memberships. Fuzzy image processing is an attempt to translate the ability of human reasoning into computer vision problems [1]as it provides an intuitive tool for inference from imperfect data. Fuzzy image processing consists of three stages: 1) image fuzzification, 2) modification of membership values, and 3) image defuzzification. Fuzzification can be considered as coding of image data, where as defuzzification can be considered as decoding of the results. The main power of fuzzy image processing lies in the modification of membership values. Appropriate fuzzy techniques modify the membership values, such as a fuzzy clustering, a fuzzy rule-based approach etc.
Many algorithms for image segmentation using fuzzy techniques have been proposed.One popular technique involves using the fuzzy c-means (FCM) algorithm, or variants of it, to compute the membership values for different classes before the final segmentation. Bezdek proposed the fuzzy C-means algorithm in 1973 as an improvement over earlier K-means clustering .Fuzzy c-means clustering [2]is a data clustering algorithm in which each data point belongs to a cluster to a degree specified by a membership grade. Fuzzy C-means partitions a collection of n vector $X_i, i = 1,...,n$ into C fuzzy groups, and finds a cluster center in each group such that a cost function of dissimilarity measure is minimized. The major difference between Fuzzy C-means and K-means is that fuzzy C-means employs fuzzy partioning such that a given data point belong to several groups with the degree of belongingness specified by membership grades between 0 and 1.To accommodate the introduction of fuzzy partitioning, the membership matrix is allowed to have elements with values between 0 and 1.However, imposing normalization stipulates that the of degrees of belongingness for a data set always be equal to unity. The main objective of fuzzy C-means clustering algorithm is that it tries to achieve to minimize total intra-cluster variance. The FCM algorithm [3]always converges to a strict local minimum of objective function, but note that different choices of the initial fuzzy membership can lead to different local minima. This implies that the FCM clustering algorithm could render a different partition matrix for a different random initial membership, especially when the given number of clusters is large.
The FCM algorithm assigns membership value to a data sample based on its proximity to the cluster prototypes in the feature space. In the FCM-based segmentation algorithm, feature vectors are assumed to be independent of each other and independent of their spatial coordinates. However, real-world images usually have strong correlation between neighboring pixels. Adjacent pixels in an object are generally not independent of each other. Thus, the incorporation of local spatial interaction between adjacent pixels in the fuzzy clustering process can produce more meaningful classification, as well as help to resolve classification ambiguities due to overlap in intensity value between clusters or noise corruption[4]. In addition, the intensity of objects or regions in an image usually varies with image location, due to illumination and/or object

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geometry. Such objects or regions can not be adequately represented by cluster prototypes of constant value.In many situations, we also need more thoroughness in designing membership functions to execute the local fuzzification because noise and outliers may falsify membership values .

2. History

Dynamic visual information from the lip movement can significantly improve the accuracy and robustness of an automatic speech recognition system in a noisy environment[5] .Biometric identification is an automatic identification procedure or verification of a person based on his/her physiological or behavioral traits. Some human traits currently utilized included fingerprints, speech, facial patterns, iris, retina and hand-written signature .Enrique Gomez et al [6]used multi labeled discrete hidden Markov model (HMM) for polar coordinates of the envelope and multilayer neural neural network for geometric height and width lip envelope description. D.J.Lee et al [7]built a system which helps people to produce sounds correctly. The system consists of two parts, the internal tongue contact pattern data collection and the external lip shape information analysis. Morphological operations were used to extract shape contour.Chengliang et al analyzed the relationship between acoustic speech and corresponding lip features such as lip width ,inner lip height and outer lip height which are acquired by an extraction algorithm combining both color and edge information with in a Markov Random field (MRF).Canny edge detector [8]used to get edge information in this algorithm.

3. Methodology

The lip image is first enhanced to correct intensity levels. Next the image is smoothed with Gaussian filter to remove blurring as preprocessing step. Now the smoothed image is clustered using proposed FCM algorithm to get membership map. Gray scale morphological filtering applied on the membership map obtained to smooth it for eliminating erroneous blobs and holes.Finally, the lip membership map is smoothed with a Gaussian filter before applying conventional segmentation algorithms Canny and Sobel separately to obtain final segmentation.

Proposed FCM Algorithm

Step 1:
Choose the number of clusters c, with 1 < c < n , the fuzziness exponent ϕ, with $\phi > 1$, value for the stopping criterion $\in$.

Step2:
Initialize the membership matrix from the obtained image which is spatially connected using geometric mean filter to reduce noise.

Step 3:
Calculate cluster centroids C_i using the equation(1).

$$C_i = \frac{\sum_{j=1}^{n} m_{ij}^{\phi} X_j}{\sum_{j=1}^{n} m_{ij}^{\phi}} \qquad i = 1,2,......,c \quad ....(1)$$

Step 4:
Calculate objective function J using equation(2).

$$J(M,C) = \sum_{i=1}^{c}\sum_{j=1}^{n} m_{ij}^{\phi} d_{ij}^{2} \qquad .....(2)$$

subject to

$$\sum_{i=1}^{c} m_{ij} = 1 \qquad j = 1,2,...,n$$

$$\sum_{j=1}^{n} m_{ij} > 0 \qquad i = 1,2,...,c$$

$$m_{ij} \in \{0,1\}$$

Step 5:
Recalculate membership matrix m_{ij} using equation(3).

$$m_{ij} = \frac{d_{ij}^{2/(\phi-1)}}{\sum_{k=1}^{c} d_{kj}^{2/(\phi-1)}} \qquad j = 1,2,...,n\,;\; i = 1,2,...,c \qquad .....(3)$$

where

$$d_{ij} = \left\| C_i - X_j \right\|$$

Step 6:
Compare the new membership matrix with the old membership matrix as follows. If $\|M^{(it)} - M^{(it-1)}\| < \in$ & objective function< $\in$ then stop; return to step 3 where $\| . \|$ is the Euclidian norm.

Step 7:
After finding the clusters, each pixel in the original image is replaced with its cluster mean as adoptive quantization.

4.Discussions

The performance of the FCM algorithm is poorer because it is not guaranteed to return a global optimum of objective function J, where the final result is very dependent on the starting points .The incorporation of spatial interactions between neighboring pixels in the clustering seems to make the convergence more consistent in the sense that the same solution is observed for different starting points. This is in contrast to the FCM algorithm. In FCM, membership matrix is initialized as random function. Hence there is no relationship between the image given and the membership map matrix. In FCM, clusters are formed based on the initial membership matrix ,there by cluster indexing will vary based on the starting points. To avoid this problem , instead of taking randomized function, part of the geometric mean filtered image is considered. Geometric mean filter operation done as neighborhood processing to maintain spatial connections while reducing noise which may falsify clustering. Lip membership map is evaluated on geometric mean filtered image. Grayscale morphological closing and opening with three-neighborhood and five- neighborhood structuring elements are used to smooth the membership map and eliminate small erroneous blobs and holes. The morphological closing is realized by performing dilation followed by an erosion, using the same structuring element for both operations. The same threshold value taken as 0.45 for all images while doing Canny edge detection process. Here to compare the performance of traditional FCM and proposed FCM, ground truth synthetic edge images are generated corresponding to their original lip images. While generating ground truth synthetic edge image, teeth edge is also considered. Here in this paper teeth region is also considered along with lip region for segmentation. Even though teeth region pixels having high intensities in RGB images which can adversely affect the clustering result ,but we obtain better results for segmentation of teeth region as well as lip region by using algorithms FCM and Proposed FCM. These two algorithms were tested with different lip images and experimental results of two lip images shown in this paper. The original lip images shown in Figures 1&2 are same which can be treated as almost closed lip. The original lip images shown in Figures 3&4 are same which can be treated as open lip with uneven teeth region. Because of spatial connectivity of pixels, we have got satisfactory segmentation results even for uneven teeth region . The Table 1 shows that the proposed algorithm gives better results over traditional FCM if Canny edge detection algorithm used where as satisfactory with Sobel edge detection algorithm.

Quantitative evaluation procedure

For edge detection, there are several comparison methods exist. As an objective quantitative measure and to compare edge preservation performances we have chosen Pratt's Figure of Merit [9][10]. This measure has often been used in edge detection evaluation which we will use to compare our results with those of others in case the test images are the same. Pratt’s Figure of Merit (FOM) also attempts to balance three types of errors that can produce erroneous edge maps: missing valid edge points, failure to localize edge points and classification of noise fluctuations as edge points. It is defined in equation(4).

$$FOM = \frac{1}{\max\left(I_D, I_I\right)} \sum_{i=1}^{I_D} \frac{1}{1+\alpha d_i^2} \qquad .....(4)$$

In this equation, I_D and I_I are the number of detected and ideal edge pixels respectively, and the parameter α is a scaling constant typically set to 1/9, while d is the Euclidean distance from an actual edge pixel to the nearest ideal edge pixel. FOM ranges between 0 and 1, with unity for ideal edge detection. Note that the Pratt’s Figure of Merit strongly depends on what method is used to obtain a binary edge map and the truth ground image.

Table1: FOM Calculations with FCM and Proposed FCM algorithms

Algorithms	Lip1		Lip2	
	canny	Sobel	Canny	Sobel
FCM	0.3498	0.3798	0.4590	0.3249
Proposed FCM	0.4124	0.3589	0.4992	0.3545

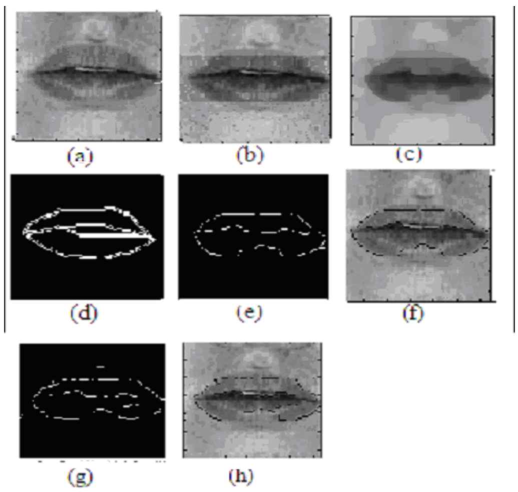

Figure.1. Lip1 images after segmenting using (FCM) algorithm:(a)Original; (b) Lip membership map; (c)After morphological filtering; d)Ground truth(e) After Canny edge detection; (f) Final segmentation with Canny;(g) After Sobel edge detection;(h) Final segmentation with Sobel .

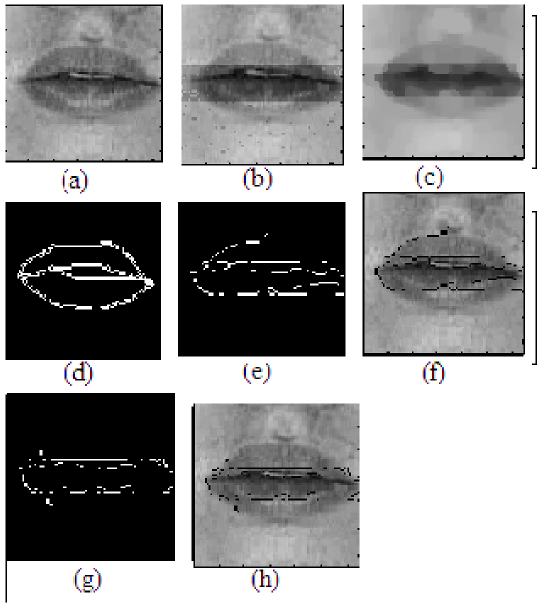

Figure.2. Lip1 images after segmenting using (Proposed FCM) algorithm:(a)Original; (b) Lip membership map; (c)After morphological filtering; d)Ground truth(e) After Canny edge detection; (f) Final segmentation with Canny;(g) After Sobel edge detection;(h) Final segmentation with Sobel.

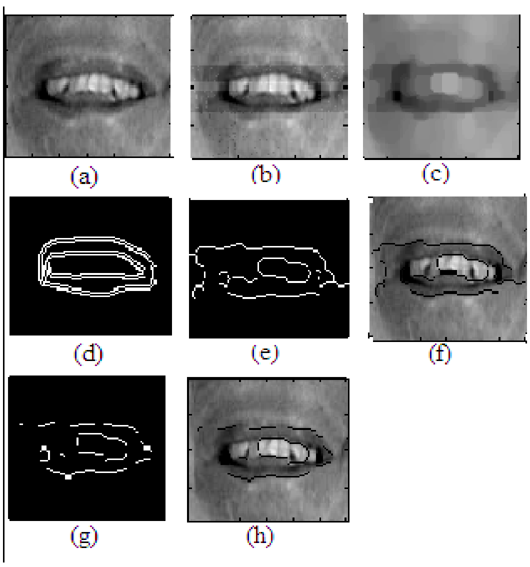

Figure.3. Lip2 images after segmenting using (FCM) algorithm:(a)Original; (b) Lip membership map; (c)After morphological filtering; d)Ground truth(e) After Canny edge detection; (f) Final segmentation with Canny;(g) After Sobel edge detection;(h) Final segmentation with Sobel.

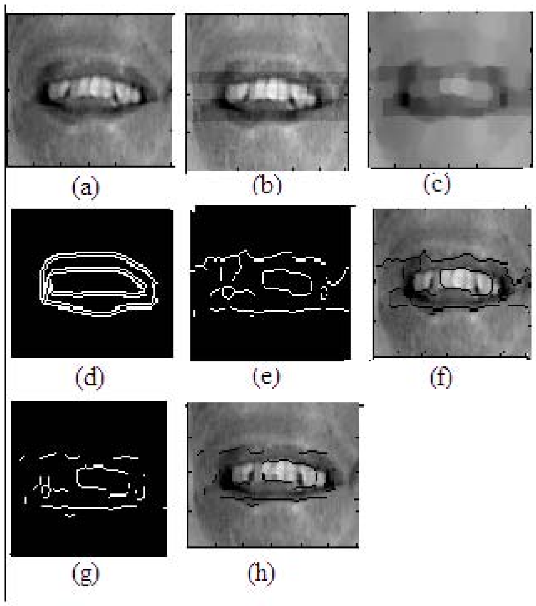

Figure.4. Lip2 images after segmenting using (Proposed FCM) algorithm:(a)Original; (b) Lip membership map; (c)After morphological filtering; d)Ground truth(e) After Canny edge detection; (f) Final segmentation with Canny;(g) After Sobel edge detection;(h) Final segmentation with Sobel

4. Conclusions

Segmentation of lip images with accuracy is difficult problem due to the weak contrast between the lip and the face region. In this paper, the lip segmentation problem is formulated as two class clustering and segmentation problem. The proposed fuzzy clustering algorithm is able to exploit the spatial interactions between neighboring pixels through the modification of initial membership function. In this paper not only the lip region, teeth region is also considered. Edge detection is done by using Sobel and Canny conventional filters.The methods are compared with the Pratt"s Figure of Merit and the obtained results are relatively satisfactory by using proposed method.

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