Journal of information and communication convergence engineering
http://jicce.org

J. Inf. Commun. Converg. Eng. 15(1): 49-52, Mar. 2017 Regular paper

Ganglion Cyst Region Extraction from Ultrasound Images Using Possibilistic C-Means Clustering Method

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Abstract

Ganglion cysts are benign soft tissues usually encountered in the wrist. In this paper, we propose a method to extract a ganglion cyst region from ultrasonography images by using image segmentation. The proposed method using the possibilistic c-means (PCM) clustering method is applicable to ganglion cyst extraction. The methods considered in this thesis are fuzzy stretching, median filter, PCM clustering, and connected component labeling. Fuzzy stretching performs well on ultrasonography images and improves the original image. Median filter reduces the speckle noise without decreasing the image sharpness. PCM clustering is used for categorizing pixels into the given cluster centers. Connected component labeling is used for labeling the objects in an image and extracting the cyst region. Further, PCM clustering is more robust in the case of noisy data, and the proposed method can extract a ganglion cyst area with an accuracy of 80% (16 out of 20 images).

Index Terms: Clustering, Cyst, Fuzzy stretching, Possibilistic c-means, Ultrasonography

I. INTRODUCTION

Ganglion cysts are benign soft tissues usually encountered in the wrist. They may occur in any joint [1]. Ganglion cysts are more common (three times more) in women than in men, and a majority occur in people between 20 and 40 years of age. Cysts can change their size or disappear completely without reason in some cases but may reappear years later [2]. A ganglion cyst can also arise from the radioscaphoid or scaphotrapezial joint volarly. These locations can cause joint instability, weakness, and limitation of motion [3].

Ultrasonography is used for diagnosis and provides guidance for treatment. It is cost-effective, has a high spatial resolution with a dynamic assessment potential, does not entail irradiation, and does not need contrast media administration [2]. To achieve better diagnostic results, we proposed a method to extract a ganglion cyst region by using possibilistic c-means (PCM) clustering.

II. EXTRACTION PROCEDURE

Fig. 1 shows the steps to extract the cyst region. The first step is fuzzy stretching. It is performed for better image enhancement. The median filter is used as the second step to reduce the speckle noise from the ultrasonography image. Then, the cyst region is segmented using PCM clustering. Thereafter, the cyst is extracted using connected component labeling.

Received 02 March 2017, **Revised** 17 March 2017, **Accepted** 24 March 2017
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Open Access http://doi.org/10.6109/jicce.2017.15.1.49 print ISSN: 2234-8255 online ISSN: 2234-8883

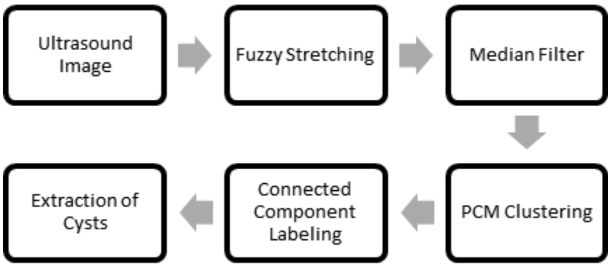

Fig. 1. Extraction of the cyst region.

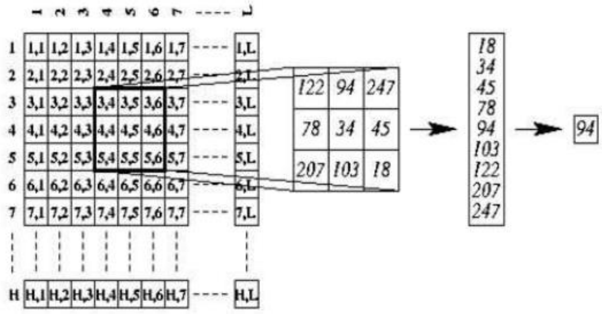

Fig. 2. Example of a 3 × 3 median filter application [5].

III. METHODOLOGY

A. Fuzzy Stretching

Fuzzy stretching is an image enhancement technique that does not need any upper or lower value limits because it dynamically controls the upper and lower range of the stretching by using a triangle-type fuzzy membership function [4].

The first step is to compute the average brightness value as follows:

$$x_m = \sum_{i=0}^{255} x_i \frac{1}{MN} , \tag{1}$$

where M and N denote the width and the length of the image, respectively.

Then, the distance between the brighter area and the darker area, and the average are computed

$$d_{max} = |x_h - x_m| , \tag{2}$$

$$d_{min} = |x_m - x_l| , \tag{3}$$

where x_h and x_l denote the highest and the lowest intensity pixel value, respectively.

The brightness value is adjusted using the following rule:

$$\begin{aligned}
&\text{If } (x_m > 128)\ ad = 255 - x_m \\
&\text{Else if } (x_m \le d_{min})\ ad = d_{min} \\
&\text{Else if } (x_m \le d_{max})\ ad = d_{max} \\
&\text{Else } ad = x_m \\
&I_{max} = x_m + ad \\
&I_{min} = x_m - ad.
\end{aligned} \tag{4}$$

Here, I_{max} and I_{min} denote the maximum and the minimum intensity, respectively.

Then, I_{mid} is computed as follows:

$$I_{mid} = \frac{I_{max} + I_{mid}}{2} . \tag{5}$$

The last step of this stretching can be expressed as follows:

$$x^G = 255 \frac{x-\gamma}{\beta-\gamma} , \tag{6}$$

where x^G denotes the new brightness value. γ represents the lower and β indicates the higher boundary of the intensity in the following formula:

$$\gamma = (I_{mid} - I_{min})\alpha\text{-cut} + I_{min}, \tag{7}$$

$$\beta = -(I_{max} - I_{mid})\alpha\text{-cut} + I_{min}. \tag{8}$$

α-cut is computed as follows:

$$\begin{aligned}
&\text{If } (I_{min} \neq 0)\ \alpha\text{-cut} = \frac{I_{min}}{I_{max}} . \\
&\text{Else } \alpha\text{-cut} = 0.05.
\end{aligned} \tag{9}$$

B. Median Filter

Median filter is a method to reduce speckle noise. This is a spatial filtering operation used for removing defects and noise from pictures. It performs better when the image sharpness is not reduced. From the neighbor of pixel P, a list of 9 (3 × 3) pixels is sorted. The median value is the value at the center of the sorted list. Every pixel to be filtered is replaced by the median value of the neighboring pixel [6]. The example of a 3 × 3 median filter is shown as Fig. 2.

C. PCM Clustering

PCM clustering is an unsupervised clustering method where the component generated by PCM corresponds to a dense region in the dataset. PCM is more robust in the case of noisy data. The PCM membership degree refers to the degree of ‘typicality’ between data and clusters [7].

The objective function in PCM clustering can be calculated as follows:

$$\begin{aligned}
\mathrm{J(U,V)} = &\sum_{k=1}^{n}\sum_{i=1}^{c} u_{ik}^{m} d^2(x_k, v_i) \\
&+ \sum_{i=1}^{c}\eta_i \sum_{k=1}^{n}(1-u_{ik})^2 ,
\end{aligned} \tag{10}$$

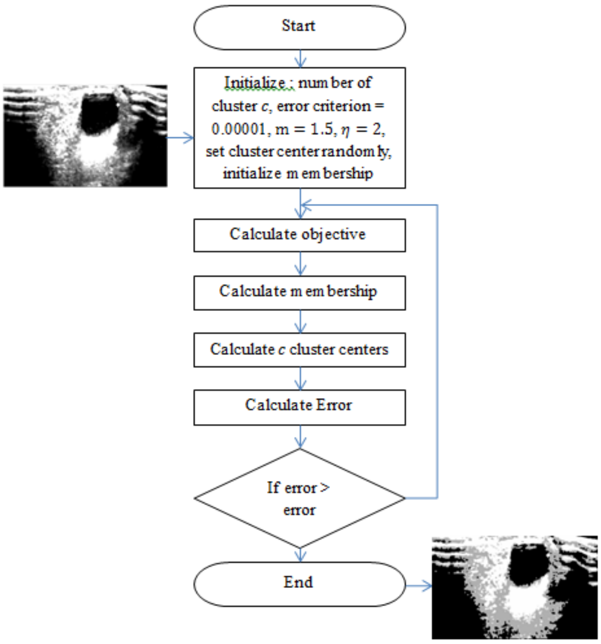

Fig. 3. Flowchart of the PCM process.

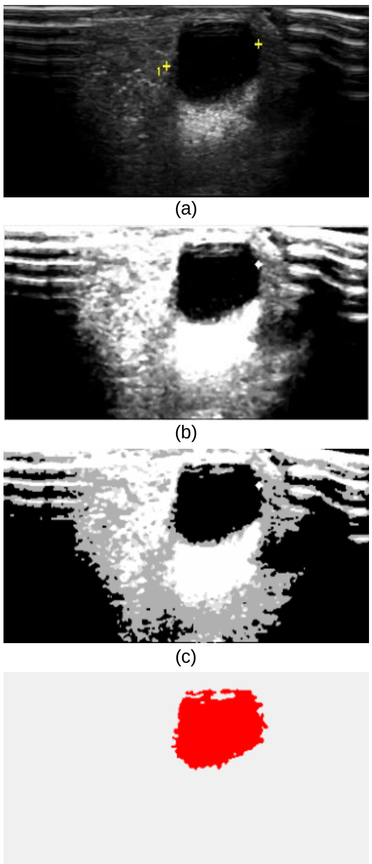

Fig. 4. Extraction result: (a) original image, (b) after the fuzzy stretching and median filter process, (c) after the PCM clustering process, and (d) after the connected component labeling process.

where η_i denotes a positive number whose value can be fixed or can be changed and u_{ik} represents the following membership equation:

$$u_{ik} = \frac{1}{1+\left[\frac{d^2(x_k,v_i)}{\eta_i}\right]^{1/(m-1)}} \quad (11)$$

The detailed PCM behavior is summarized as Fig. 3.

D. Connected Component Labeling

Connected component labeling is a simple and efficient algorithm. It is applied after image segmentation. It is called connected component if the pixels have similar color and are adjacent to each other. Every connected component in the image is labeled uniquely. Connected component analysis is very dependent on an efficient method for segmenting images into regions [8]. The algorithm is as follows [9]:

Step 1: Set the foreground and background colors.

Step 2: Iterate through each data item by column and then, by row.

Step 3: If the element is not the background, set the current data label to be the same as the neighbor data label. If there are no neighbors, create a new label for the data.

Step 4: After the first iteration, perform the second iteration to re-label the data by using the lowest equivalent label.

IV. RESULTS

The application is created using the programming language Visual Studio 2010 C#. There are 20 ultrasonography images of a ganglion cyst on a wrist. In this study, the α_cut value is fixed according to the mean pixel intensity. If the image intensity is less than 40, the α_cut value is 0.05. Otherwise, the α_cut value is 0.6. Before the implementation of fuzzy stretching, the program calculates the mean pixel intensity. After the median filter process, PCM clustering is performed. The parameters are as follows: stopping error criterion = 0.00001; “fuzzifier” m = 1.5; number of clusters = 4. The parameter η is a fixed value. In this study, $\eta = 2$. Connected component labeling extracts the cyst region by labeling each object in the image. The darkest color is set as the foreground color. Very small and very large labeled objects are removed as noise.

The accuracy of the proposed method is 80%; that is, 16 out of the 20 images are successfully extracted.

Fig. 4 demonstrates an example that was successfully extracted by the proposed method.

Failure occurs in the following two scenarios: the connected component labeling process fails to extract the object if the cyst region is still connected with another object in the image. Further, failure occurs when the labeled clusters are not connected to each other; thus, the proposed algorithm underestimates the ganglion cyst area (in case the cyst is not gathered in one location).

V. CONCLUSION

Proposed method as presented herein using PCM clustering method is applicable for ganglion cyst extraction. The methods in this thesis are fuzzy stretching, median filter, PCM clustering, and connected component labeling. Fuzzy stretching performs well in ultrasound image and improve original image into better visual appearance. In this experiment, ganglion cyst extraction accuracy is 80% which is there's opportunity to improve the accuracy using better methods.

In future, we will expand our research to other part of the body (i.e., ganglion cyst in knees or fingers).

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