Follicle Detection in Digital Ultrasound Images using Bi-dimensional Empirical Mode Decomposition and Fuzzy C-means Clustering Algorithm

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Abstract: Ultrasound Imaging is one of the technique used to study inside human body with images generated using high frequency sounds waves. The applications of ultrasound images include examination of human body parts such as Kidney, Liver, Heart and Ovaries. This paper mainly concentrates on ultrasound images of ovaries. The detection of follicles in ultrasound images of ovaries is concerned with the follicle monitoring during the diagnostic process of infertility treatment of patients. Monitoring of follicle is important in human reproduction. This paper presents a method for follicle detection in ultrasound images using Bi-dimensional Empirical Mode Decomposition and Fuzzy C-means clustering algorithm. Bi-dimensional Empirical Mode decomposition is used for contrast enhancement of ovary image and Fuzzy c-means algorithm is used to segment the ovary image. After segmentation, using the region properties of the image, the follicles in the ovary image are identified. The proposed algorithm is tested on sample ultrasound images of ovaries for identification of follicles and with the region properties, the ovaries are classified into three categories, normal ovary, cystic ovary and polycystic ovary with its properties. The experiment results are compared qualitatively with inferences drawn by medical expert manually and this data can be used to classify the ovary images.

1. INTRODUCTION

PCOS (Polycystic Ovarian Syndrome) is one of the common disorder seen in females of reproductive age. The disorder is characterized by the formation of many follicular cysts in the ovary. The main cause of this disorder in females is due to menstrual problems, hirsutism, endocrine abnormalities, acne, obesity etc [1]. The detection of ovarian follicle is done using ultrasound images of ovaries. Object recognition in an ultrasound image is a challenging task which includes the detection of follicles in ovary, growth of the foetus, monitoring of proper development of the foetus and presence of tumor [2]. Now a days the diagnosis performed by doctors is to manually count the number of follicular cysts in the ovary, which is used to judge whether PCOS exists or not. This manual counting may lead to problems of variability, reproducibility and low efficiency. Automating this mechanism will resolve these problems. In literature, less work done in automating PSOC diagnosis.

In case of normal ovary, under influence of right levels of hormones FSH and LH (i.e. Follicle Stimulating Hormone and Luteinizing Hormone), only one follicle grows in size to about 20 mm in diameter, matures and becomes ready for ovulation. In PCOS affected ovary, due to reduced levels of FSH and LH and high levels of prolactine, follicles fail to grow and attain maturity. Thus, in ultrasound image of PCOS affected ovary, large number of small follicles (typically 12 or more and about 2-9 mm in diameter) can be seen distributed along the periphery of the ovary, classically described as 'necklace formation [3]. Moreover, the ovarian volume in such patients is typically increased over 10 cm^3. Figure 1 shows ultrasound image of normal ovary showing only one follicle ready for ovulation. Whereas, figure 2 shows numerous small follicles present along the periphery of the ovary [4]. In this paper, an algorithm for identification of follicles in ovarian images is presented using Bi-dimensional Empirical Mode Decomposition and Fuzzy c-means clustering algorithm. The experiment results are compared with inferences drawn by medical expert manually and identifies the ovary images more accurately than manual segmentation.

The paper is organized as follows: Section II presents contrast Enhancement using Bi-dimensional Empirical Mode Decomposition (BEMD), Section III presents Fuzzy C-means clustering algorithm (FCM), Section IV presents Identification of follicles in Ovary Ultrasound Images using BEMD and FCM, Section V presents Experimental results, and finally Section VI reports conclusion.

Figure 1: Normal Ovary

Figure 2: PCOS affected Ovary

2. CONTRAST ENHANCEMENT USING BI-DIMENSIONAL EMPIRICAL MODE DECOMPOSITION

The EMD proposed by Dr. Norden Huang [5], was a technique for analyzing nonlinear and non-stationary signals. It serves as an alternative to methods such as wavelet analysis and short-time Fourier transform. It decomposes any complicated signal into a finite and often small number of Bi-dimensional Intrinsic Mode Functions (IMF). The IMF is symmetric with respect to local zero mean and satisfies the following two conditions.

1. The number of extrema and the number of zero crossings must either be equal or differ by one.
2. At any point, the mean value of the envelope defined by local maxima and local minima is zero, indicating the function is locally symmetric.

The decomposition method in EMD is called Shifting Process [6]. The shifting process of the two-dimensional signal such as image can be adapted from the one-dimensional signal as follows.

1. Let $I_{original}$ is defined as an image to be decomposed. Let j=1 (index number of IMF), I= $I_{original}$ (the residue).
2. Identify the local maxima and local minima points in I.
3. By using interpolation, create the upper envelope E_{up} of local maxima and the lower envelope E_{lw} of local minima.
4. Compute the mean of the upper envelope and lower envelope.

$$E_{mean} = [E_{up} + E_{lw}]/2$$
(1)

5. $I_{imf} = I - E_{mean}$.
(2)
6. Repeat steps 2-5 until I_{imf} can be considered as an IMF.
7. IMF(j)= I_{imf}, j=j+1, I = I- I_{imf} ,
(3)
8. Repeat steps 2-7 until all the standard deviation of two consecutive IMFs is less than a predefined threshold or the number of extrema in I is less than two.

The first few IMFs obtained from BEMD contain the high frequency components which correspond to salient features in original image and the residue represents low frequency component in the image. The original image can be recovered by inverse BEMD as follows [7]:

$$I = RES + \sum_j IMF(j)$$
(4)

The BEMD process for generation of IMFs of the ovary ultrasound image are shown in figure 3.

Image Contrast Enhancement: If the contrast of the ovary image is low, the quality of the edges of follicles extracted from the ovary image will be poor. The quality of the ovary image can be improved by applying this BEMD based contrast enhancement algorithm to the original image prior to the computation of identification of follicles.

i. First divide the Ovary image into Intrinsic Mode Functions (IMF) by using Bi-dimensional Empirical Mode

International Journal of Research in Advent Technology, Vol.6, No.11, November 2018
E-ISSN: 2321-9637
Available online at www.ijrat.org

Decomposition.

$$BEMD(F) = [imf_1, imf_2, ..., imf_n]._{\backslash}$$

ii. The enhanced image is obtained by the summation of IMFs, with each IMF multiplied by weight w_i. The summation of the weights should be equal to one.

$$EMI = \sum_{i=1}^{n} w_i * imf_i$$

(5)

Where w_i denotes the weight of ith imf and EMI represents the enhanced microarray image.
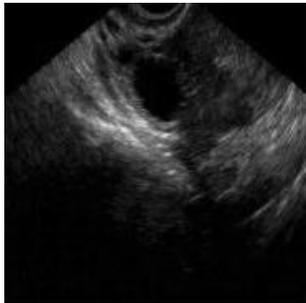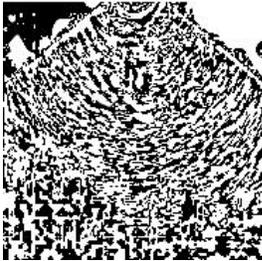
Ultrasound Ovary Image		Ultrasound Ovary Image (Contrast Enhanced)	
IMF1	IMF2	IMF3	IMF4

Figure 3: IMF of ultrasound image

3. FUZZY C-MEANS CLUSTERING ALGORITHM

The Fuzzy c-means clustering algorithm [8] for segmentation of ovary image is described as follows:

1. Randomly consider K initial clusters $\{C_1, C_2, ..., C_k\}$ from the m*n image pixels $\{I_1, I_2, I_3, ..., I_{m*n}\}$.
2. The membership matrix u_{ij} is initialized with value from 0 to 1 and value of m=2. The summation of pixel memberships representing particular cluster should be equal to 1.
3. Assign each pixel to the cluster C_j $\{j=1,2,.....K\}$ if it satisfies the following condition

$$u_{ij}^m D(I_i, C_j) < u_{iq}^m D(I_i, C_q), q = 1,2,...,K$$

$$j \neq q$$

(6)

Where D(. , .) is the Euclidean distance measure between two values.

4. Find new membership and cluster centroid values as follows

$$u_{ik} = \frac{1}{\sum_{j=1}^{K} (\frac{D(C_i, I_k)}{D(C_j, I_k)})^{\frac{1}{m-1}}}, \, for 1 \leq i \leq K \quad u_{ik}$$

denotes the kth object in the ith cluster.

International Journal of Research in Advent Technology, Vol.6, No.11, November 2018
E-ISSN: 2321-9637
Available online at www.ijrat.org

$$C_i^{\wedge} = \frac{\sum_{j=1}^{n} u_{ij}^m I_j}{\sum_{j=1}^{n} u_{ij}^m}$$

(7)

Where n is the number of pixels belonging to cluster C_i.

5. Continue 2-3 until each object is assigned to the cluster that has maximum membership [9].

4. FOLLICLE IDENTIFICATION IN OVARY ULTRASOUND IMAGE

The main steps of the identification of follicles in ovary image are summed up as follows:

1. The ultrasound image is processed by BEMD based contrast enhancement algorithm, then an image with sharper contrast is obtained.
2. Apply FCM algorithm to segment the contrast enhanced ovary image
3. Convert the segmented image into binary image and edges are extracted using canny operator.
4. Perform Mathematical Morphology operations on the resulting image to remove isolated pixels and to replace thick lines with thin lines.
5. Use imfill function to fill the holes. These holes denote follicles in ovary image.
6. Using the region properties, we can extract the features of follicles such as major axis length, minor axis length, area, centroids etc. With this features, ovaries are classified into normal ovary, cystic ovary and polycystic ovary..
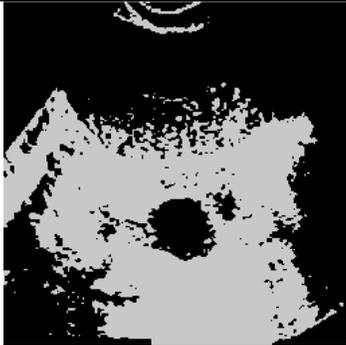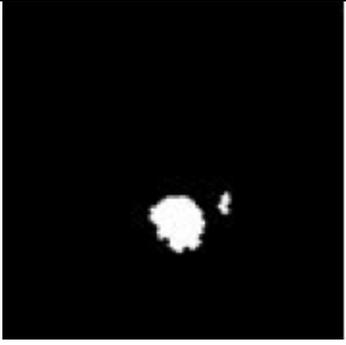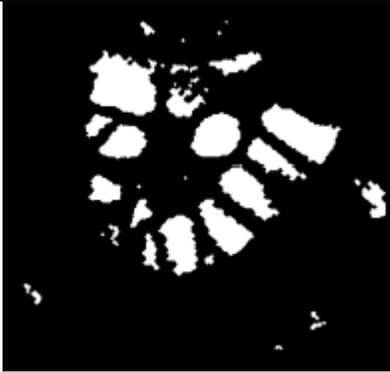
5. EXPERIMENTAL RESULTS

In this section, the proposed method is used to detect the follicles in ovary ultrasound images. Ovary images are obtained from the publicly available websites www.radiologyinfo.com[11,12],www.ovaryresearch.com [10] . The image1 and image2 is taken from dataset D1 with size 256*256. The qualitative analysis of the proposed method is shown in figure 4 compared with manual segmentation.

6. CONCLUSION

The information about the status of female reproductive system is important for problems related to fertility and family planning. The ultrasound imaging is an effective tool in infertility treatment. Monitoring the follicles in ultrasound images in terms of number, size, shape and position is important in human reproductive system. In this paper, a methodology of identification of follicles in ultrasound images is presented. The proposed method uses Bi-dimensional empirical mode decomposition procedure, to extract first intrinsic mode functions and each IMF is multiplied by weight w_i. The summation of weighted IMFs gives the contrast enhanced image. After enhancement, the image is segmented using FCM algorithm. By using region properties, the follicle regions in the ultrasound image are identified. This proposed method is compared qualitatively with manual segmentation. In future this follicle information is used to classify the ovary images into three classes, normal ovary, cystic ovary and polycystic ovary using the region properties of identified follicles.

Ovary Image 1	Contrast Enhanced using BEMD
Segmented using FCM	Follicle identification

International Journal of Research in Advent Technology, Vol.6, No.11, November 2018
E-ISSN: 2321-9637
Available online at www.ijrat.org

Ovary Image 2	Contrast Enhanced using BEMD
Segmented using FCM	Follicle identification
Manual Segmentation Ovary Image 1	Manual Segmentation Ovary Image 2

International Journal of Research in Advent Technology, Vol.6, No.11, November 2018
E-ISSN: 2321-9637
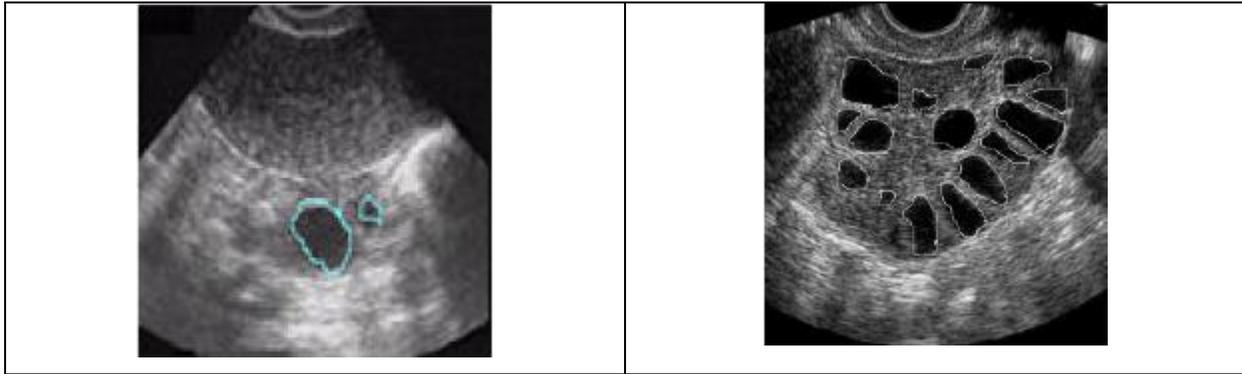*Available online at www.ijrat.org*

Figure 4: Follicle detection in ovary ultrasound image

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