

Detection of Cysts in Ultrasonic Images of Ovary

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Abstract: In this paper, cysts are detected in the ultrasonic images of ovary. PCOS is an endocrine disorder affecting women of reproductive age. This syndrome is mainly seen in women whose age is in between 25 and 35. We are proposing methods for identifying whether a person is suffering from Polycystic Ovary Syndrome (PCOS) or not. Ultrasound imaging of the follicles gives important information about the size, number and mode of arrangement of follicles, position and response to hormonal stimulation. A thresholding function is applied for denoising the image in the wavelet domain. Before the segmentation process the ultrasonic image is preprocessed using contrast enhancement technique. Morphological approach is used for implementing contrast enhancement. This is performed in order to improve the clarity and quality of the image. Fuzzy c-means clustering algorithm is applied to the resultant image. Finally the cysts are detected with the help of clusters. The efficiency of the algorithm depends upon the value of Mean Square Error (MSE) and Peak Signal to Noise Ratio (PSNR).

Keywords: Denoising, Contrast Enhancement, Morphological Operations, Segmentation, Fuzzy C-Means Clustering.

1. Introduction

Cysts are follicles which have abnormal size. Based on the detection of follicles, the suspected patient can be treated as normal or polycystic. Ovarian follicles are roughly spherical, fluid-filled structures in which oocytes (eggs) develop. Follicles imaged in two dimensions appear as dark, roughly circular regions in ultrasound images since fluid does not reflect ultrasonographic pulses. PCO ovaries typically exhibit a larger number of smaller, possibly irregularly shaped follicles, and a peripheral distribution of follicles. The ultrasonographic morphology of a polycystic ovary (PCO) is characterized by the presence of 12 or more ovarian follicles which are 2-9 mm in size. These follicles are termed as cysts. The symptoms of PCOS are menstrual irregularity, obesity, hyperandrogenism, diabetes, acne, increased risk of cardiovascular disease, male-pattern facial and bodily hair growth and balding, excessive production of male hormones, infertility etc. An automatic detection of cysts for a PCOS patient is implemented using fuzzy c-means clustering. Before performing this algorithm we are denoising and contrast enhancing the ultrasonic image which is given as the input.

Diagnostic ultrasound uses frequency between 2 and 15 MHz. Ultrasonic waves are produced from the transducer and penetrates into the body tissues and when the wave reaches an object or a surface with different texture or acoustic nature, some fraction of the energy is reflected back. The echoes so produced are received by the apparatus and changed into electric current. These signals are then amplified and processed to get displayed on CRT (Cathode Ray Tube) monitor. The image so obtained is called ultrasound scan and the process is known as ultrasonogram. This image is given as the input. Ultrasound imaging technique is inexpensive and is very effective for cyst recognition. The overall quality of the ultrasound image is the end product of a combination of many factors originating from the imaging system and the performance of the operator. Ultrasonic image may contain noises due to loss of proper contact or air gap between transducer and body part. Noises can also be formed during beam forming process or signal processing. The noises may cause the image blurred and thereby lead

to poor segmentation. Hence we are performing denoising. A soft thresholding function is proposed for the process of removing noise.

Contrast enhancement increases the appearance of large-scale light-dark transitions of an image. The edges of the image become clearer. This process automatically brightens images that appear dark or blurred and applies appropriate correction to deliver optimal quality and clarity. Morphological operations are performed for contrast enhancement technique. Fuzzy c-means clustering algorithm is applied for the segmentation of follicles from the ultrasonic image. The purpose of clustering is to identify natural groupings of data from a large dataset to produce a concise representation of a system's behavior. The follicles are detected inside the ovary and the obtained results are compared with the manual results.

2. Proposed Methodology

Figure 1 gives the schematic diagram of the proposed methodology.

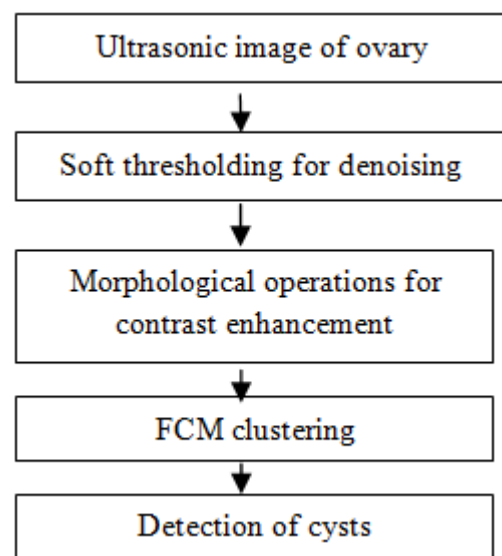


Figure 1: Block Diagram for cyst detection

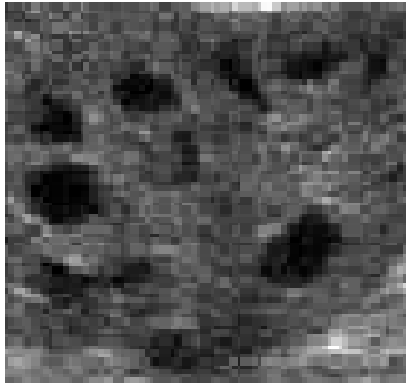


Figure 2: Original Ultrasonic Image (Input)

3. Denoising using Soft Thresholding

Ultrasonic images may be affected by noise in different stages of image processing. Therefore image denoising is an unavoidable step. Denoising is simply the process of removing noise. Here we are adding noise to increase the signal wavelength. The noisy image is shown in Figure3.

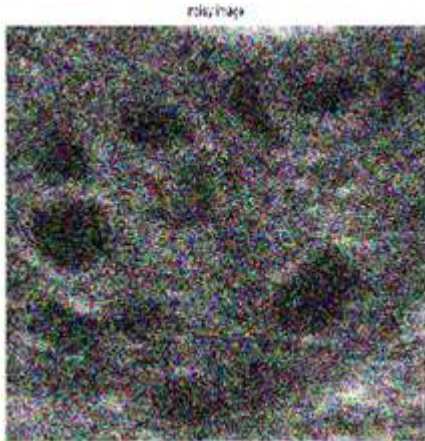


Figure 3: Noisy Image

We are proposing a soft thresholding function for image denoising in the wavelet domain. Wavelet transform has become an important tool to suppress the noise. Wavelet transform of a noisy signal is a linear combination of the wavelet transform of the original signal and the noise. The power of the noise can be suppressed with a suitable threshold while the main features can be preserved. Wavelet coefficients of a noisy image are divided into important and non-important coefficients and each of these groups are modified by a certain rule called thresholding rule.

At the initial stage, the noisy image is decomposed in the wavelet domain. Based on a thresholding function, detailed coefficients are modified by selecting a suitable threshold value. The universal threshold is calculated as:

$$thr_{universal} = \sigma \sqrt{2 \ln(n)} \quad (1)$$

where σ is the standard deviation.

Thresholding function proposed by Ref [3] is defined by Eq. (2):

$$\eta(x, thr, k) = \begin{cases} x + thr - \frac{thr}{2k + 1} & x < -thr \\ \frac{1}{(2k + 1)thr^{2k}} x^{2k+1} & |x| \leq thr \\ x - thr + \frac{thr}{2k + 1} & x > thr \end{cases} \quad (2)$$

The proposed thresholding function has lower risk value than others in fixed threshold value. Therefore it is a more powerful function. In order to improve the flexibility and capability of the proposed function, three shape tuning factors have been added which may lead to a comprehensive thresholding function that can be adjusted to any desired thresholding function. The shape tuning factors are 'k', 'm' and 'n'. If the value of 'k' is 1, then the function is a hard thresholding function and if the value is 0 then it indicates soft thresholding function. The value of 'm' and 'n' determines the shape of the function for coefficients that are bigger and lesser than absolute threshold value respectively. So here we are tuning the parameter 'k' to 0 since we are performing soft thresholding. The three shape tuning factors are added to the proposed thresholding function as follows:

$$\eta(x, thr, m, n, k) = \begin{cases} x + 0.5(-thr)^m \times \frac{k}{x^{m-1}} - (k - 1)thr & x < -thr \\ 0.5 k \times \frac{|x|^n}{thr^{n-1}} \text{sign}(x) & |x| \leq thr \\ x - 0.5 thr^m \times \frac{k}{x^{m-1}} + (k - 1)thr & x > thr \end{cases} \quad (3)$$

where $n = m + 2 - k/k$.

Finally the denoised image can be obtained by reconstructing the original image. The original image which is free of noises can be reconstructed using Inverse Discrete Wavelet Transform (IDWT).

The efficiency of the denoising method using thresholding function can be calculated using the Mean Square Error (MSE). Lesser the value of MSE, higher will be the efficiency of the algorithm. The value of MSE can be calculated using Eq. (4):

$$MSE = \frac{1}{r \times c} \sum_{i=1}^r \sum_{j=1}^c ((B(i, j) - A(i, j))^2) \quad (4)$$

Here, A (i,j) is the noisy image of size $r \times c$, where 'r' is the number of rows and 'c' is the number of columns. B (i,j) is the denoised image.

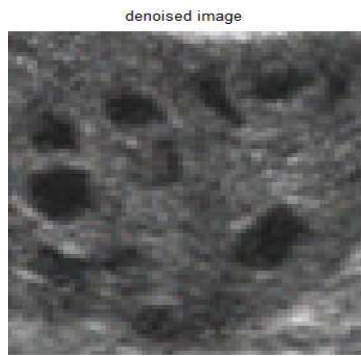


Figure 4: Denoised image

4. Contrast Enhancement

Contrast enhancement makes the denoised image more clear and distinct. The edges of the follicles can be easily identified by performing this technique, in other words the edges are being sharpened so that the follicles can be clearly seen. We are performing morphological operations for contrast enhancement.

Morphology is a broad set of image processing operations that process images based on certain shapes. Morphological operations apply a structuring element to an input image. The structuring element can be diamond, disk, line or ball shaped. It can also take some other shapes. In a morphological operation, the value of each pixel in the output image is based on a comparison of the corresponding pixel in the input image with its neighbors. Here since we are detecting follicles and these follicles are disk shaped, we are choosing a disk shaped structuring element. Then we can construct morphological operation. We are implementing two methods of morphological operations: i) Morphological opening and closing. ii) Tophat and Bottomhat filtering.

4.1 Morphological opening and closing

The initial stage is to create a structuring element. A structuring element is a matrix which consists of only zeros and ones that can have a disk shape and a specific size.

Dilation is the process of adding pixels to the boundaries of objects in an image. Erosion is the process of removing pixels on object boundaries. Dilation and erosion are used in combination to perform image processing operations. Erosion followed by dilation is termed as morphological opening of an image where as dilation followed by erosion is known as morphological closing of an image. Morphological opening extracts bright features of an image and morphological closing extracts dark features of an image. By combining these two images, we get contrast enhanced image.

4.2 Tophat and Bottomhat filtering

Like morphological opening and closing, for this process also create a structuring element. Morphological tophat filtering is performed on the grayscale denoised input image. This can be used to correct uneven illumination when the background is dark. Therefore tophat filtering

extracts brighter features of an image. Bottomhat filtering is implemented on the denoised image and as a result of this the filtered image is obtained. This highlights darker features of an image. Tophat filtering and bottomhat filtering can be used together to enhance contrast in an image.

The two methods mentioned above were performed for the process of contrast enhancement. The second method (tophat and bottomhat filtering) was found to be more effective. This made the image clearer when compared to the other method. Figure 5(a) gives the contrast enhanced image using morphological opening and closing and Figure 5(b) gives the contrast enhanced image using tophat and bottomhat filtering.

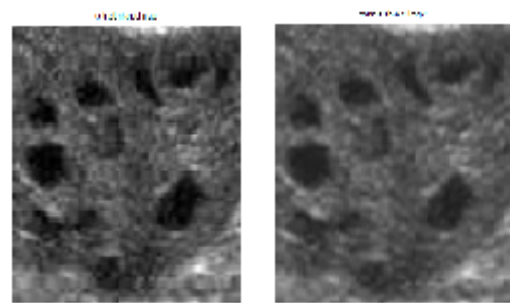


Figure 5(a)

Figure 5(b)

5. Fuzzy C-Means Clustering

Fuzzy C-Means (FCM) clustering is used for detecting the follicles. FCM is a data clustering technique in which each data point belongs to a cluster. These clusters have some degree and those are specified by certain membership functions. The intention behind clustering is that to identify natural groupings of data from a given dataset. Fuzzy C-means clustering algorithm is applied to the contrast enhanced image. Clustering simply is a group of data with similar characteristics. In a grayscale image, this method allows one pixel to belong to two or more clusters. A finite collection of pixels in an image are partitioned into a collection of "C" fuzzy clusters with respect to a given criterion. Based on the feature values, segmentation can be performed.

Fuzzy C-means Clustering algorithm is based on the objective function by eq. (5):

$$O(M, c_1, c_2, c_3, \dots, c_n) = \sum_{i=1}^n O_i = \sum_{i=1}^n \sum_{j=1}^l m_{ij}^w e_{ij}^2 \quad (5)$$

O : Objective function

M: Membership matrix ($M = [m_{ij}]$)

c_i : Centroid of cluster i

e_{ij} : Euclidian distance between i^{th} centroid (c_i) and j^{th} data point.

w: $\in [1, \infty]$ is a weighting exponent

5.1 Fuzzy C means Algorithm

Fuzzy c means algorithm is shown below :

Step1: Initialize the matrix, $M = [m_{ij}]$ which is the membership matrix.

Step2: At k^{th} number of iteration, calculate the vectors c_i :

$$c_i = \frac{\sum_{j=1}^l m_{ij}^w y_j}{\sum_{j=1}^l m_{ij}^w} \quad (6)$$

where y is the reduced dataset.

Step3: Update the membership matrix M for the k^{th} step and $(k + 1)^{th}$ step:

$$m_{ij} = 1 / \sum_{k=1}^n (e_{ij} / e_{kj})^{2/(w-1)} \quad (7)$$

where $e_{ij} = y_j - c_i$

Step4: If $||U(k + 1) - U(k)|| < \epsilon$ then stop, otherwise go to step 2.

The image obtained after performing the above algorithm is the segmented image. The performance of segmentation is calculated using Mean Square Error (MSE). The formula for MSE is given in the eq.4. But here $A(i,j)$ is the manually segmented image and $B(i,j)$ is the segmented image formed using fuzzy c-means algorithm. If the value of MSE is lesser, then we can conclude that the efficiency of the algorithm is better. Figure5 gives the segmented image.

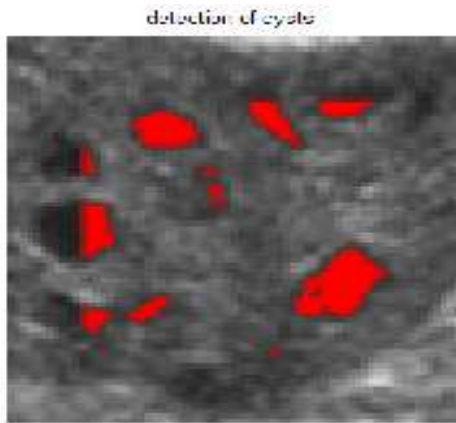


Figure 6: Segmented image

6. Experiment and Results

The three proposed methods applied for different stages of follicle detection ie thresholding function for denoising, morphological operations for contrast enhancement and fuzzy c-means algorithm for segmentation are tested on about 40 ultrasonic images of ovary. The results obtained after denoising, contrast enhancement and segmentation are shown in Figure 4, 5 and 6 respectively. Figure 5(a) and 5(b) gives the images which are contrast enhanced by using morphological opening & closing and tophat & bootomhat filtering respectively. Among these two methods, tophat & bottomhat filtering are found to be more effective. Figure 7(a), Figure 7(b) and Figure 7(c) gives the original ultrasonic image of ovary1, manually segmented image of ovary1 and fcm segmented image of ovary1 respectively. Figure 8(a) Figure 8(b) and Figure 8(c) gives the original ultrasonic image of ovary2, manually segmented image of ovary2 and fcm segmented image of ovary2 respectively. Figure 9(a), Figure 9(b) and Figure 9(c) gives the original ultrasonic image of ovary3, manually segmented image of ovary3 and fcm segmented image of ovary3 respectively.

The MSE of the segmented follicle of the image is lesser when compared to the MSE of the manually segmented image The PSNR values are also calculated. The value of PSNR is comparatively higher. This proves the efficiency of the proposed algorithm. The experimental results of 3 ultrasonic images are shown in the Table 1.

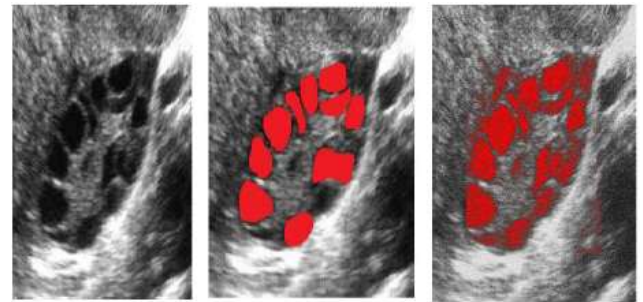


Figure 7(a)

Figure 7(b)

Figure 7(c)

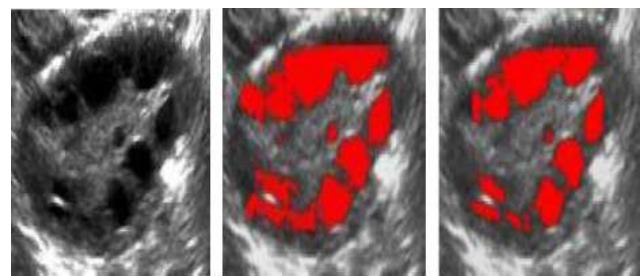


Figure 8(a)

Figure 8(b)

Figure 8(c)

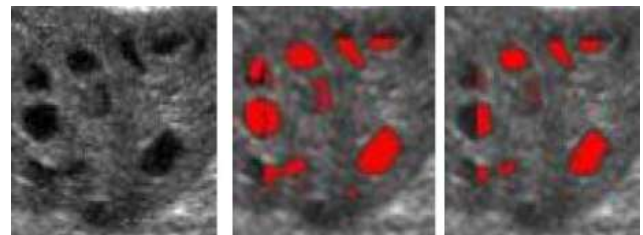


Figure 9(a)

Figure 9(b)

Figure 9(c)

Table 1: Experimental Results

| Image | Noise Type | Variance | PSNR |
|---------|------------|----------|---------|
| Ovary 1 | Gaussian | 0.05 | 24.4919 |
| | | 0.10 | 21.5140 |
| | Speckle | 0.05 | 29.2129 |
| | | 0.10 | 26.6271 |
| Ovary 2 | Gaussian | 0.05 | 22.9811 |
| | | 0.10 | 22.9484 |
| | Speckle | 0.05 | 24.0935 |
| | | 0.10 | 24.0595 |
| Ovary 3 | Gaussian | 0.05 | 25.0645 |
| | | 0.10 | 23.7720 |
| | Speckle | 0.05 | 23.3826 |
| | | 0.10 | 23.4099 |

In the Table 1, we can see that there are 3 ultrasonic images of ovaries - Ovary1, ovary2 and ovary3 .We are adding two types of noises- Gaussian and Speckle. The standard values 0 for mean and 0.05 and 0.10 for variance are given as input. Even though adding noise the PSNR value calculated is high. This indicates the efficiency of the proposed algorithm.

7. Conclusion

In this paper we have used soft thresholding function for the purpose of image denoising in the wavelet domain. Morphological operations have been applied for contrast enhancement and fuzzy c-means algorithm was implemented for segmentation. Finally the cysts are detected. This algorithm makes the detection of cysts easier and less time consuming. The higher value of PSNR indicates better performance of the algorithm. They can reduce the burden of experts. Within a small period of time, ultrasonic images of a number of suspected patients can be screened.

8. Acknowledgement

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