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A Novel Pigeon Inspired Optimization in Ovarian Cyst Detection

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Abstract: Follicular cyst is characterized by the fluid filled sac presence in the female ovary. Ultrasound imaging system is the one commonly used for this cyst diagnosis. In this system, transvaginal ultrasound is used to take a look into women's reproductive system, the uterus and ovaries. Presently, while scanning, the radiologists manually trace the details of the follicular cysts, its number and size which is painful for the patients. In this paper, a novel optimization technique called Pigeon Inspired Optimization (PIO) algorithm is proposed to obtain the optimal threshold value for automatic detection of follicular cyst from the ovarian image and extract it features. The proposed method effectively obtains the threshold value by maximizing the between class variance of the modified Otsu method. The automatic follicular cyst detection system proposed in this paper reduces the error in manual detection and time taken for diagnosis. The proposed PIO algorithm has been compared with Invasive Weed Optimization (IWO). The experimental results show that the proposed method finds the better solution and converges faster than the IWO.

Keywords: Follicular cyst, objective function, ovary, pigeon inspired optimization, segmentation, threshold.

1. INTRODUCTION

The ovary is a part of female reproductive system that appears on both sides of the uterus. Today, cyst is one of the most common disorders found in women ovaries and are of different kinds. Most of the ovarian cysts are not cancer, but may have to be properly treated for well being of women. The follicles in an ovary are responsible for the release of matured egg, after which the eggs travel through the fallopian tube for fertilization. In few cases, the follicle doesn't release the egg that in a later stage, manifests as a cyst [1-7]. The symptoms of follicular cyst are irregular menstrual period, weight loss and abdominal swelling. Transvaginal ultrasound imaging technique has been used for imaging the internal organs. Gynecologists monitor the ovaries periodically by ultrasound examination to diagnose the follicular cyst, during which, the number, size and shape of the follicular cysts are manually calculated. This process is time consuming and painful for the patients. Hence, an automatic and accurate cyst detection system has to be modeled for timely diagnosis and treatment.

In the literature, Deng *et al.* introduced an automatic system for the detection of polycystic ovary syndrome from ovarian images, which uses morphological filter to reduce the speckle noise and labeled watershed algorithm to find the contours. Finally, the region growing algorithm has been used [8]. PS *et al.* introduced edge based method and active contour method for the segmentation of follicles from ultrasound medical images [9, 10]. Cai *et al.* modified the thresholding technique into tri class thresholding technique. This method is applied on nuclei microscopic images. In general, Otsu based thresholding method classified the image into two classes, but in cases of tri class thresholding the image is divided into three regions. The third region is the determined region [11]. Based on literature, it is clear that only a few authors have worked on ultrasound ovary images.

Recently, in the literature, it is observed that many authors have introduced algorithms based on biological behavior to optimize values. Holland introduced genetic algorithm (GA) for engineering applications. Kennedy and Eberhart presented particle swarm optimization to solve optimization problems. Passino developed population based algorithm called Bacterial Foraging Optimization (BFO). Dorigo *et al.* presented Ant colony Optimization (ACO) based on the behavior of ant colonies. From the facial images, the lips are segmented using thresholding techniques based on BFO [12]. Kumar *et al.* introduced image segmentation method based on optimization techniques and its variants. The results are compared with other known optimization techniques [13]. Gao *et al.* introduced ACO method to maximize the extra class variance for obtaining a better threshold value for image segmentation [14]. Xizng *et al.* presented a new PSO method for image clustering. This method has been applied on medical images and the experimental results show better performance as compared to existing clustering methods [15]. The genetic algorithm is applied on various images for segmentation. The well known thresholding technique, called, the Otsu method has been optimized using various optimization techniques [16]. Li and Li introduced an image segmentation technique by fuzzy entropy based on particle swarm optimization. The experimental results provide satisfactory results [17, 18]. Mehrabian and Lucas have introduced Invasive Weed Optimization (IWO) enthused from the behavior of weed colonization [19]. The IWO optimization has been applied to solve prob-

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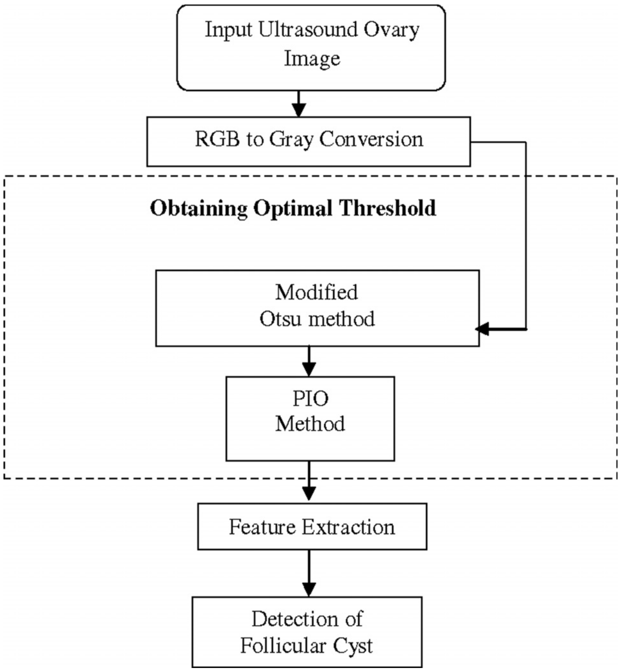

Fig. (1). The block diagram of the proposed method.

lems in electromagnetic and antenna array problems [20–24]. Roy *et al.* presented modified invasive weed optimization for circular antenna array application [25]. A novel swarm intelligence algorithm, namely, Pigeon Inspired Optimization (PIO) technique was invented by Duan in 2014 [26]. The PIO technique imitates the homing behavior of pigeons, from which the map and compass operator and landmark operator have been designed. In aerospace path planning problem, the PIO method is applied to find the best path [27, 28].

This paper intends to give an opening for the Pigeon Inspired Optimization (PIO) algorithm to medical images. This technique has been applied for automatic detection of follicles from ultrasound ovarian images. The performance of this novel PIO method is compared with the other nature inspired optimization technique, namely, the Invasive Weed Optimization (IWO) algorithm. Various optimization techniques have been presented in the literature to solve the problem in medical imaging. Many of the optimization techniques are fast, but fail to achieve a global optimum solution. The proposed PIO is a powerful technique in terms of quicker convergence and finding an optimal solution for threshold. The ovarian image is then segmented with this threshold value. The proposed automatic cyst detection system will thus detect the cysts accurately and reduce the time taken for diagnosis. In addition, the proposed system can relieve the patients from painful observation.

The flow of the proposed method is described in Section 2. The proposed PIO algorithm is presented in Section 3. Section 4 describes the results and discussion and the conclusion is derived in Section 5.

2. METHOD

The block diagram of the proposed systems is shown in Figure **1**. The ultrasound ovarian image is given as an input to the automatic follicular cyst detection system. The input image is converted from RGB scale to gray. Threshold value for segmenting the cyst is optimized using the proposed PIO algorithm. Next, the features of the cyst are extracted from the segmented results.

3. THE PIO ALGORITHM

In this section, problem formulation, fitness evaluation, and the implementation of the Pigeon Inspired Optimization algorithm are presented. PIO algorithm follows the pigeon's behavior. The pigeons soar to their target place by observing the sun and store the path in their brain. Once the pigeons come near to the targeted place, they start depending on the landmarks near to the targeted place. Also, they might follow the pigeons that are already familiar about the landmarks. The PIO algorithm is described as follows.

Initialization

Initialize population size P_N, the search space, maximum number of iterations for map and compass operator Nm_{max} and number of iterations for the landmark operator Nl_{max} and compass factor R_0. Each pigeon is initialized with randomized position and velocity.

Map and Compass Operator

Let Po_j and V_j denote the pigeons' position and its corresponding velocity in search space. The new velocity V_j and position Po_j of pigeons at the s_{th} iteration can be calculated from Eqn. 1 and 2.

$$V_j = V_j(s-1)\ e^{-R_o s} + rand\ (Po_{gbest} - Po_j(s-1)) \quad (1)$$

$$Po_j(s) = Po_j(s-1) + V_j(s) \quad (2)$$

where R_o denotes the map and compass factor, *rand* represents a random number, and Po_{gbest} is the *gbest* position. The positions of all the pigeons have been compared to identify the *gbest* position. The map and compass operator surely find the best positions of the pigeons. This process is stopped when maximum number of iterations Nm_{max} reached [26].

Landmark Operator

In each iteration, the pigeon population P_N is reduced into half, which is done by Eqn. 3.

$$P_N(s) = \frac{P_N(s-1)}{2} \quad (3)$$

All the pigeons are ranked based on their fitness values. The pigeon having lowest fitness value has to follow the pigeon who have the highest fitness value. The center of the pigeons is calculated using Eqn. 4 and this center is the enviable target position.

$$Po_{cen} = \frac{\sum Po_j(s)\ fit(Po_j(s))}{P_N \sum fit(Po_j(s))} \quad (4)$$

The pigeons are adjusting their flying direction using Eqn. 5.

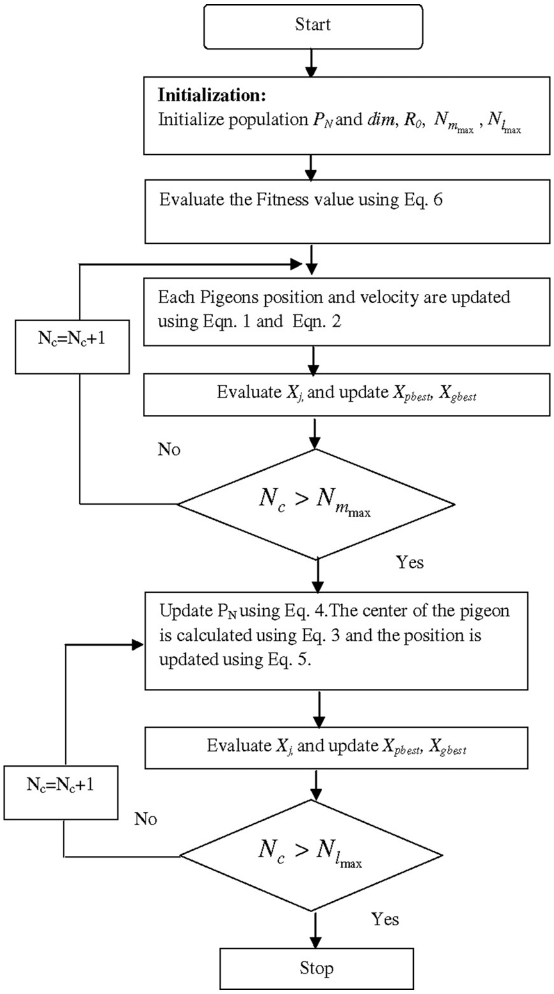

Fig. (2). The flow chart of the proposed PIO.

$$Po_j(s) = Po_j(s-1) + rand\ (Po_{cen}(s) - Po_j(s-1)) \quad (5)$$

where Po_{cen} represents the center position of the pigeon, P_N is the pigeon population and *fit* denotes the fitness of the pigeon. For maximization problem, the fitness is calculated by using the formula $fit\left(Po_j(s)\right) = f_{max}\left(Po_j(s)\right)$. The landmark operator is stopped when reaching the maximum number of iterations Nl_{max} [27].

3.1. Problem Formulation

The first step of the optimization algorithm is to formulate the problem. The input to the optimization algorithm is ultrasound ovarian images. Generally, the probability of having follicular cyst in women undergoing infertility treatment is more. During ovulation, the ovum inside the follicle is released. Sometimes, due to hormonal imbalance, the follicle fails to release the egg, as a result follicle size enlarges and over the time, it becomes a follicular cyst. Depending upon the size of the cyst, gynecologist recommends the appropriate treatment to the patient. The size of the cyst determines the type of treatment, if too large it has to be removed by surgery otherwise can be treated by oral medicines. This necessitates accurate detection of the cyst and determining its size. An optimal threshold value is needed to extract the follicles from the ovary. PIO algorithm, based on pigeons homing behavior is proposed for optimizing this threshold. It maximizes the between class variance of the modified Otsu method to find the optimal threshold value for detection of follicular cyst.

3.2. Fitness Evaluation

This section describes the fitness function of the PIO method. The initial threshold value of the modified Otsu method is calculated iteratively, the between class variance is then maximized to determine the best threshold value. Using the average pixel values of the ovarian image, an image is split into two classes. During, the first iteration the average mean of the two classes t[k] is identified [11] and this new value replaces the previous threshold value t[k-1]. This step will continue until it converges to t[k]-t[k-1]. On convergence, there will not be any change in threshold value for forthcoming iterations. Finally, this iteratively obtained threshold value is used in conventional Otsu method to separate the image into two classes. The mean and standard deviation of the two classes are calculated. The between class variance of the modified Otsu method is given by Eqn. 6.

$$\sigma^2_{Bet}(th) = S_1(\mu_{g_1} - \mu_{th})^2 + S_2(\mu_{g_2} - \mu_{th})^2 \quad (6)$$

where S_1 and S_2 are the probabilities. μ_{g_1} and μ_{g_2} are the mean of the two classes, μ_{th} is the total mean of the ovarian image. This between class variance is maximized using the PIO algorithm. The performance of the proposed PIO based Otsu method outperforms the existing thresholding techniques.

3.3. Implementation of PIO to Obtain the Optimal Threshold

The automatic follicular cyst detection system is implemented using the PIO algorithm to find the optimal threshold value. The objective of the proposed PIO algorithm is to maximize the between class variance. The initial step of the proposed algorithm is to initialize the parameters and each pigeon is initialized with the random position and velocity. Each pigeon may give a possible solution. Then, the fitness value is calculated using Eqn. 6. To find the current best path of the pigeon, fitness of the each pigeon are compared. The velocity and position of the pigeon is updated in map and compass operator phase by using Eqn. 1 and Eqn. 2.The new best path has been found by comparing the fitness of the pigeon in the new position. This process is repeated until the map and compass operator iteration reaches the maximum. In the landmark operator phase, the pigeons are ranked according to their fitness [26-28]. By using Eqn. 3, the pigeon's population is diminished into half. Then, the center of the pigeon is discovered, according to Eqn. 4. Based on Eqn. 5, all the pigeons are changing their flying direction to reach the center.

The best position and the fitness values are stored. This phase is stopped until landmark iteration Nl_{max} reaches its maximum. Hence, from the obtained threshold, the follicular cyst is identified. The shape features of the follicles are extracted for further diagnosis. The flow chart of the proposed PIO algorithm is given in (Fig. **2**).

Table 1. Parameter values for proposed PIO and IWO

PIO		IWO	
Parameter	**Value**	**Parameter**	**Value**
Initial Population	100	Initial Population	100
Maximum Iteration	100	Population Maximum	150
R_0	0.5	Maximum Iteration	100
-	-	Se_{min}	3
-	-	Se_{max}	5
-	-	S_{ini}	3
-	-	S_{fin}	0.005
-	-	nmi	3

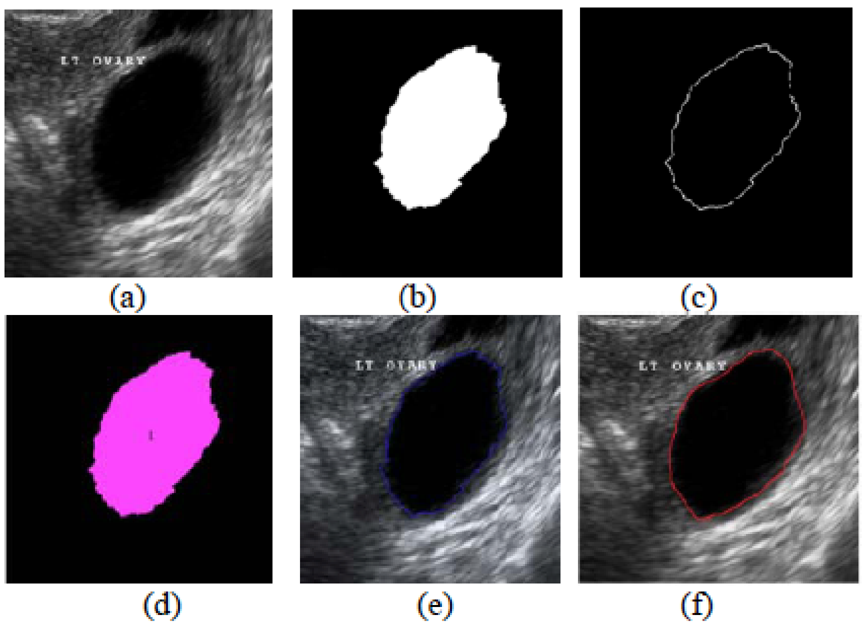

Fig. (3). Follicular Cyst Detection: a) Original image b) Segmentation result by proposed PIO c) Edge detected result d) Identified follicular cyst e) Overlaid on original image f) Follicular cyst detection by medical expert.

4. RESULTS AND DISCUSSION

The automatic follicular cyst detection system proposed in this paper reported efficient results. The follicles are traced accurately from the ovary images by using the proposed method. The experiments have been implemented on Hp Pavilion dv5 with Intel® Core™ 2 Duo CPU @ 2.00GHz with 3 GB RAM running on Microsoft Windows 7 platform. The methods are executed using Matlab 2012. To show the performance of the proposed method, the experiment has been conducted on 103 ultrasound ovary images. Moreover, the proposed method has been compared with the conventional IWO method. The proposed method discovered the optimal threshold value for follicular cyst detection. Furthermore, it reduces the computational time. Identifying exact number of follicles from ovary image is a difficult task. The mode of the treatment is chosen based on the number of follicles and the size of the follicles in the ovary. Hence, accurate detection of follicles plays a major role in correct diagnosis. The proposed pigeon inspired optimization is applied to the ultrasound ovarian image to find the accurate threshold value. The fitness function of the PIO algorithm is the between class variance of the modified Otsu method. The parameter settings for pigeon inspired optimization algorithm are P_N =100, R_0=0.5. The parameter values of PIO algorithm are chosen with care. The performance of the PIO method is compared with Invasive Weed Optimization (IWO) [22].

The IWO optimization follows the weeds colonization behavior. In IWO algorithm, the parameters play a major role to obtain an optimal solution. The initial and final standard deviation value, the nonlinear modulation index is chosen cautiously. The minimum and maximum number of seeds is set as 3 and 5 respectively [22]. The parameter's value for both PIO and IWO method is given in Table **1**. The follicle identified by the proposed PIO algorithm is shown in (Fig. **3**). The input ovary image is given in Fig. **3**(**a**) and the

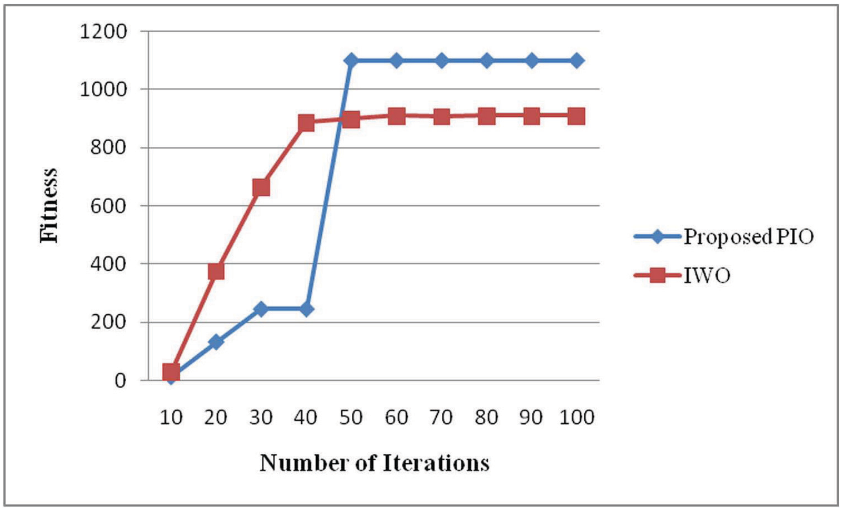

Fig. (4). Comparision plot of proposed PIO and IWO for differing number of iterations.

Table 2. Comparision of proposed PIO method and IWO method by number of follicles.

Ultrasound Ovary Images Used for testing	Total number of Follicles Detected by the proposed PIO method	Total number of Follicles Detected by the IWO method	Total number of Follicles Detected by Medical Expert
103	183	187	181

segmented result by the proposed PIO algorithm is seen in Fig. 3(**b**). The extracted follicle's edge is displayed in Fig. 3(**c**) and the follicle count is given in Fig. 3(**d**). The edge of the detected follicle is overlaid on the input image, as seen in Fig. 3(**d**) and the medical expert results are given in Fig. 3(**e**) respectively.

The proposed PIO algorithm converges quicker and finds an optimal threshold value than other existing techniques to detect the follicles from the ovarian images. From Fig. **4**, it is to be identified that the proposed PIO method converges faster than the IWO method, moreover, PIO algorithm found, a better optimal solution in fewer iterations than the existing IWO algorithm.

The IWO method could find a better optimal solution only when the standard deviation value reaches its minimum and finds the maximum fitness value in its 60_{th} iteration, but it starts converging at its 80_{th} iteration. In case of the proposed PIO, the algorithm finds the maximum fitness value in the 50_{th} iterations itself and also converges. The proposed PIO method reports a better performance than the IWO method in terms of faster convergence and finding the best solution. Table **2** shows the total number of follicles identified by the proposed PIO method, IWO method, and medical expert, for the 103 ultrasound ovarian images. Moreover, follicle cysts identified by the proposed method nearly match with the medical expert's result. Figure **5**, taken from the database of 103 images. It can be observed that the proposed PIO method identifies the follicles more efficiently than the other algorithms.

In general, the shape based features like Area, Extent, Circularity, and Tortuosity are measured to recognize the follicles. Therefore, subsequent to detection of follicle cyst, shape based features are extracted in order to identify follicles correctly. The American Society for Reproductive Medicine describes the standard detail about the size and number of follicles for correct identification of disease. The total number of pixels inside the extracted follicles is known as its area. To correctly recognize the follicle the Circularity range must be in the range of 0.2 to 0.8 and the Extent is in the range of 0.2 to 0.7. Tortuosity differs from 0.1 to 0.4. Hence, the above mentioned features are extracted to reduce the false diagnosis. Table **3** shows the extracted feature details for the follicles given in Fig. **5** and Table **4** summarizes the experimental results of the proposed PIO method, IWO method, modified Otsu method and the conventional Otsu method for three ovary images.

4. CONCLUSION

An efficient automatic follicular cyst detection system using a novel nature inspired algorithm called Pigeon Inspired Optimization technique is proposed in this paper for the detection of cysts in ovarian images captured by ultrasound imaging system. This algorithm, depends on the homing behavior of pigeons that maximizes the between class variance of the modified Otsu method and accurately extract the follicular cyst. From the extracted follicles, the shape based features are extracted for further diagnosis. The experimental results show that the proposed PIO method exceeds IWO concerning quicker convergence and precision. This automatic detection system will be a beneficial tool for the radiologists in periodic monitoring of the patients who endures infertility treatment. Moreover, this will avoid manual and painful observations on patients while using ultrasound imaging technique. Indeed, without forfeiting the accuracy, the radiologists can diagnose patients efficiently by using this automated system.

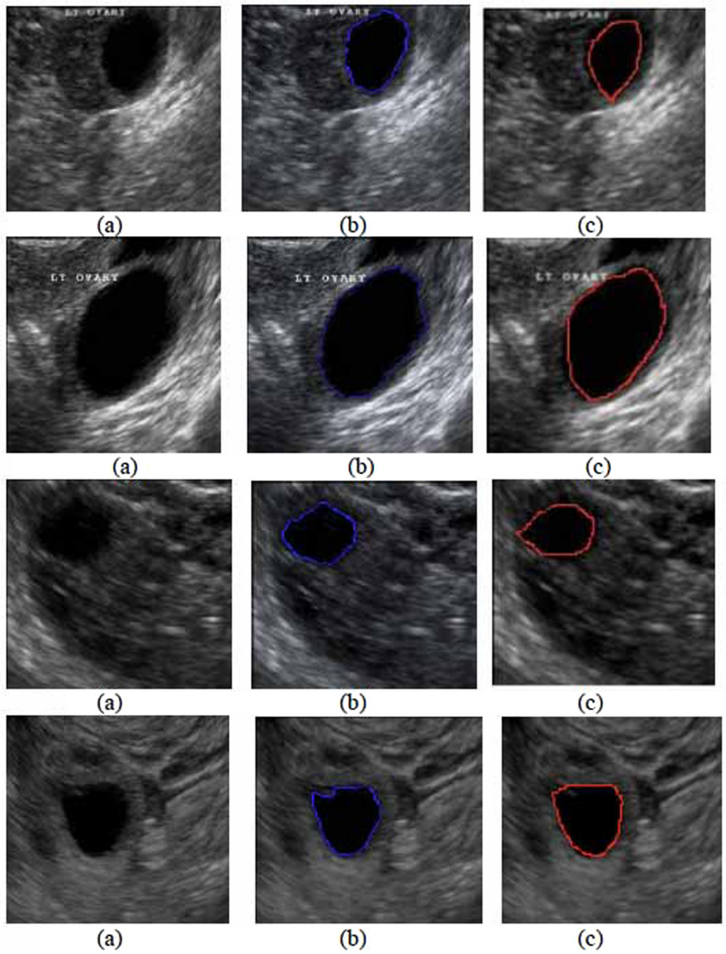

Fig. (5). Results for four input ovary images: a) original image b) segmentation result by proposed PIO method c) manual expert result.

Table 3. Features extracted from segmented follicles by proposed method.

Area	Extent	Circularity	Tortuosity
3832	0.6192	0.2153	0.1881
12234	0.6184	0.3460	0.2419
3282	0.5135	0.2354	0.2127
2007	0.5334	0.2107	0.1716

Table 4. Comparision of proposed PIO, IWO, modified otsu, otsu method results derived from extracted follicles.

Different types of ovarian Image for Experimentation	Extracted Follicles (To=Total, T=True, F=False)												
	Proposed PIO Method			IWO Method			Modified Otsu Method			Otsu Method			Results given by the Expert
	To	T	F	To	T	F	To	T	F	To	T	F	
Image1	1	1	-	1	1	-	1	1	-	2	1	1	1
Image2	1	1	-	2	1	1	2	1	1	3	1	2	1
Image3	1	1	-	1	1	-	1	1	-	2	2	1	1
Image4	1	1	-	1	1	-	2	1	1	4	1	3	1

CONFLICT OF INTEREST

The authors confirm that this article content has no conflict of interest.

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