Research Paper: Analysis of Follicle Wall of Normal and Polycystic Ovaries

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ABSTRACT

Objectives: It is important to recognize and diagnose various forms of ovulatory failure that contribute to infertility. Polycystic Ovary Syndrome (PCOS) is one such failure characterized by the formation of numerous follicles in the ovary. This disorder seriously affects women's health and it is diagnosed by ultrasound imaging which gives important information on the number of follicles and their size.

Materials & Methods: These follicles are fluid filled structures that exhibit echo texture. Texture features of the follicle wall for both normal and PCOS dominant follicles are evaluated over a period of seven days before ovulation.

Results: By considering these features, follicle growth rate is investigated in normal and PCOS.

Conclusion: The results supported the hypothesis that quantitative changes in echo texture are reflecting the changes in the physiologic status of the normal ovary.

1. Introduction

The Polycystic Ovary Syndrome (PCOS) is a complex endocrine disorder [1, 2] associated with long-term lack of ovulation and hyperandrogenism, affecting 5-10% of women in the pubertal as well as reproductive age. Symptoms of PCOS include infertility, hirsutism, acne and hypertension. Accurate diagnosis of the PCOS is very important for its treatment. The PCOS images are acquired by ultrasound imaging or ultrasonography-; ultrasound images are non-invasive and less expensive compared to other medical imaging techniques. PCOS is characterized by the presence of 12 or more ovarian follicles, of 2-9 mm size, and/or a total ovarian volume [3] of more than 10 cm^3. Contrast to this, normal ovaries usually present a random distribution and may exhibit one or two dominant follicles which, by definition, are at least 2-3mm larger than the rest. Hence, ultrasonographic imaging of ovaries is used as routine check-ups for menstrual abnormalities, infertility treatments, and/or hyper androgenic symptoms.

Research on the walls of follicles based on texture analysis is limited. Krivanek and Sonka segmented the follicle wall using watershed segmentation technique

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[4]. Sarty indicated [5] that the textures in the fluid area of ovarian follicles vary according to the stage of development of follicles in natural cycles. Texture method is employed to analyze the ovarian follicular wall during natural cycles and in PCOS [6]. The texture analysis is applied to estimate the content and distribution of fat in beep [7]. Methods based on textural feature analysis are used in identifying diffuse diseases of the liver [8]. Raeth [9] showed the progress of atherosclerosis using the texture method. Burr [10] used texture method to detect breast cancer.

The objective of this study is to identify the PCOS by analysing the growth rate between the ovaries based on the echo texture. The textures give information about physiological changes and significantly differ between women with PCOS and those with normal ovaries. Texture feature extraction described in section 2. The quantitative results are presented in section 3 and conclusions in section 4.

2. Materials and Methods

Data collection

Two hundred images of patients in the age group 25-35 years suffering from anovulatory infertility / PCOS and sets (each set consists of 7 images) of images with natural menstrual cycle and PCOS were collected from JB Diagnostic Center Bangalore. The ultrasound images were taken using a real time LOGIQ P3 (General Electricals, Milwaukee, USA) scanner with a 4.5-5.5MHz, curvilinear, broadband bandwidth transducer probe with the dynamic range set of 55dB. The ultrasound images are usually corrupted with speckle noise. In case of PCOS [2] speckle noise is more because PCOS are fluid filled sacs which produces a less acoustic impedance. Thus, it becomes essential for denoising [11], in order to improve the image quality. The ovarian follicles are fluid filled structures and have a homogeneous region (dark region). This homogeneous region is segmented by improved active contour method [12] to isolate the follicle from the background. Figure 1 shows the denoised and segmented image, the arrow marks show the follicle wall. The natural organ surfaces exhibit textures and they cannot be discriminated visually on ultrasonographic images. In this work Co-occurrence Haralick texture method is employed to analyze the ovarian follicular wall and study physiological status in women during natural cycles and the PCOS.

Extraction of Co-occurrence features

Gray level co-occurrence matrices are well-known and widely used texture measures. Let a two-dimensional image, I(x, y), (x=1, ..., M, y=1, ..., N) have N_g gray levels. A co-occurrence matrix depicts the joint gray-level histogram of the image (or a region of the image) in the form of a matrix with the dimensions of Ng×Ng. The entries are the probability density pairs of gray levels that are separated by a distance d. Suppose the cardinality of the set of pairs of points that have gray level $P_d(i, j)$ with a displacement vector d=(dx, dy) then

$$P_d(i, j)=|\{((r, s), (r+dx, s+dy)):I(r,s)=i, I(r+dx, s+dy)=j\}|$$

, where $(r, s)\in M\times N$, |.| is the cardinality of a set and *d* is distance. The co-occurrence matrix with distance 1 in the direction 00 will be $d=(1, 1)$. The calculation of matrices for other directions (450, 900, and 1350) are similar. The selection of distance d in the co-occurrence matrix is important as it depends on follicle's wall thickness. The follicle wall is found to be thin that the widths are often 1 or 2 pixels. Some parts of the follicle wall are even invisible. To measure texture feature of follicle wall, the distance d should be chosen to be equal or smaller than the width of the follicle wall. If d>2, the co-occurrence matrix measures the spatial relation-

Figure 1. Selection of follicle wall; (a): Original image; (b): Despeckled image; (c): Segmented image and arrow mark showing the follicle wall

ship between one foreground pixel and one background pixel. Therefore, any choices of d>2 should be avoided for the accuracy reason. We choose d=1 in computing co-occurrence matrices. Among the 14 Haralick texture features energy, contrast and homogeneity features are the most often used features and have been reported to be successful in many applications. The features are evaluated as follows:

$$Energy = \sum_{i=1}^{N_g}\sum_{j=1}^{N_g} p_d^2(i,j)$$

$$Homogeneity = \sum_{i=1}^{N_g}\sum_{j=1}^{N_g} \frac{p_d(i,j)}{1+|i-j|}$$

$$Contrast = \sum_{n=0}^{N_g} n^2 \sum_{|i-j|=n} p_d(i,j)$$

3. Results

The proposed method is implemented in Mat Lab 7.10 on a 2.8 GHz Intel Pentium dual core personal computer. The seven day-wise normal and PCOS images are considered in the analysis. The co-occurrence matrices of energy, homogeneity and contrast are calculated in horizontal direction (00), right-diagonal direction (450), vertical direction (900), and left-diagonal direction (1350) with distance d=1. Table 1 and Figure 2 shows the energy feature in 00, 450, 900 and 1350 directions. It may seem that normal and PCOS has larger energy values in the direction of 00 and comparatively smaller feature values in the other three directions. It's because that most of the echoes get reflected back in the 00 directions than in other direction. From Figure 2 it is observed that in a normal image energy increase from day 5 and in case of PCOS, it is almost constant from day 5.

Table 1. Co-occurrence energy features; (a): Normal; and (b): PCOS images

	Direction	Days						
		1	2	3	4	5	6	7
A	00	0.055	0.059	0.068	0.070	0.078	0.081	0.113
	450	0.052	0.057	0.059	0.053	0.053	0.058	0.069
	900	0.053	0.059	0.060	0.055	0.057	0.061	0.71
	1350	0.052	0.058	0.059	0.054	0.055	0.062	0.072
B	00	0.16	0.17	0.24	0.19	0.18	0.14	0.16
	450	0.11	0.09	0.15	0.12	0.08	0.07	0.069
	900	0.12	0.092	0.16	0.14	0.09	0.075	0.072
	1350	0.061	0.089	0.074	0.069	0.071	0.0701	0.0734

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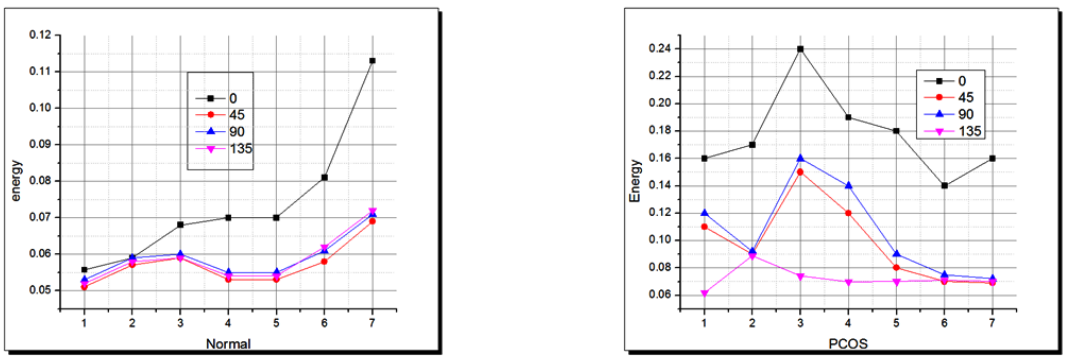

Figure 2. Energy features in four directions; (a): Follicle wall of normal image; (b): Follicle wall for PCOS image

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Table 2 . Co-occurrence Homogeneity features; (a): Normal: and (b): PCOS images

	Direction	Days						
		1	2	3	4	5	6	7
A	00	0.67	0.73	0.75	0.78	0.789	0.79	0.80
	450	0.42	0.44	0.45	0.48	0.49	0.501	0.503
	900	0.49	0.51	0.52	0.54	0.56	0.567	0.60
	1350	0.48	0.46	0.54	0.62	0.57	0.59	0.655
B	00	0.83	0.79	0.77	0.76	0.764	0.762	0.73
	450	0.7	0.62	0.64	0.634	0.639	0.61	0.509
	900	0.75	0.62	0.64	0.634	0.639	0.61	0.509
	1350	0.71	0.64	0.63	0.64	0.63	0.58	0.56

The homogeneity feature is a measure of gray-tone transition in the homogeneous image. Hence, the more homogeneous texture larger the homogeneity value. The ovaries are fluid filled sacs and homogeneity values were apparently higher in the horizontal direction (00) as shown in Table 2 and Figure 3. The normal images have increased homogeneity from day 2 to 5 and become constant from day 6. In case of PCOS, the value becomes constant from day 3 to 6 and later decreases from day 7 as shown in Figure 3.

The contrast feature is a measure local intensity variation present in an image. Feature values from both normal and PCOS were calculated in four directions similar to the above procedures of analysis. The consistently lower contrast value of the direction 00 is compared with those in the other three directions as shown in Table 3 and Figure 4. In 00 direction due to high energy and homogeneity the contrast is reduced and vice-versa in a case of 450. The contrast value for 450 reduces from day 3 in normal images and remains constant from day 2 in PCOS as in Figure (4b). Based on the above discussion, it is found find that the energy and homogeneity are high at 00 and the contrast is maximum at 450. This implies that in case of normal follicles as the day pass there will be more amount of fluid accumulation which result in an increased energy level, decrease in contrast and slight increase in homogeneity. In PCOS due to the follicular arrest the fluid accumulation will be less and which result in decrease energy level, increase in contrast and more or less constant homogeneity. Thus the PCOs exhibit a bright hyperechoic avascular wall which indicates there is no further growth.

Further analyze the growth rate of follicle in an image of normal and PCOS, follicles of size 2 mm^2, 4 mm^2,

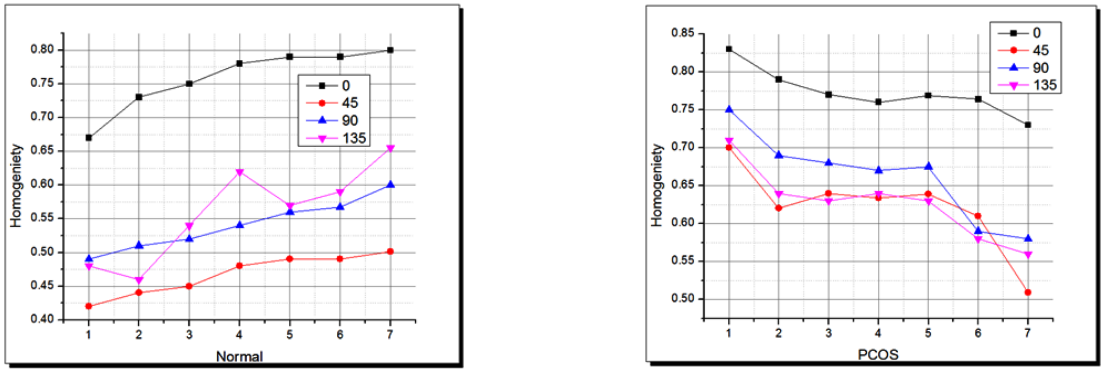

Figure 3. Homogeneity features in four directions; (a): Follicle wall of normal image; and (b): Follicle wall for PCOS image

Table 3. Co-occurrence contrast features; (a): Normal; and (b): PCOS

	Direction	Days						
		1	2	3	4	5	6	7
A	00	12.23	11.79	12.89	8.76	6.89	6.79	7.78
	450	14.80	12.13	14.45	11.90	10.90	10.98	9.70
	900	13.76	11.91	12.45	10.09	9.80	9.87	8.34
	1350	12.96	10.50	13.34	10.65	8.90	8.98	7.21
B	00	3.09	5.67	5.78	5.34	5.67	5.23	6.29
	450	5.67	7.57	7.68	7.71	7.74	7.90	8.29
	900	4.32	5.56	5.67	5.78	5.76	6.09	6.78
	1350	5.43	6.56	6.78	6.91	6.45	6.90	7.78

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6 mm^2 and 8 mm^2 are considered. The features, energy and homogeneity at 00 direction and the contrast at 450 direction are considered. The average feature values of energy, homogeneity, contrast for 210 images is computed and is plotted in Figure 5. In Figure 5 it is seen that in normal images, there is a decrease in slope for contrast and an increase in slope for energy and homogeneity. In contrast to this, the PCOS has increase in slope for contrast, decrease in slope for energy and homogeneity, which indicates no growth of follicles.

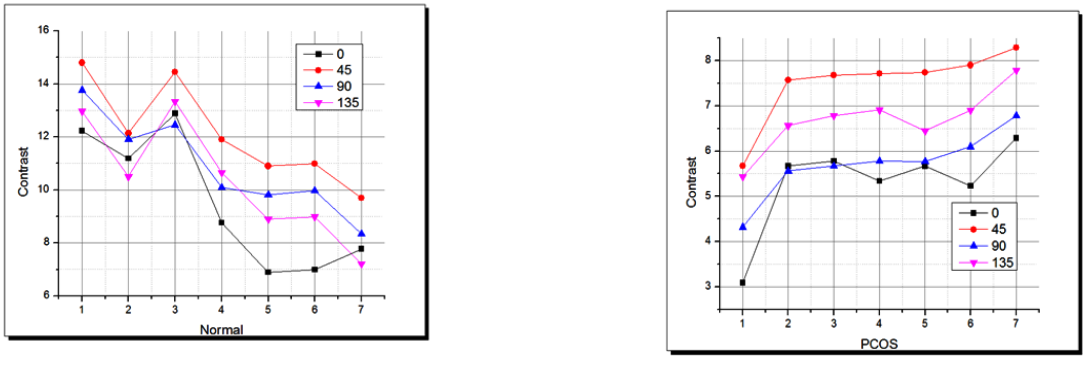

Figure 4. Contrast features in four directions; (a): Follicle wall of normal image; and (b): Follicle wall for PCOS JAMSAT

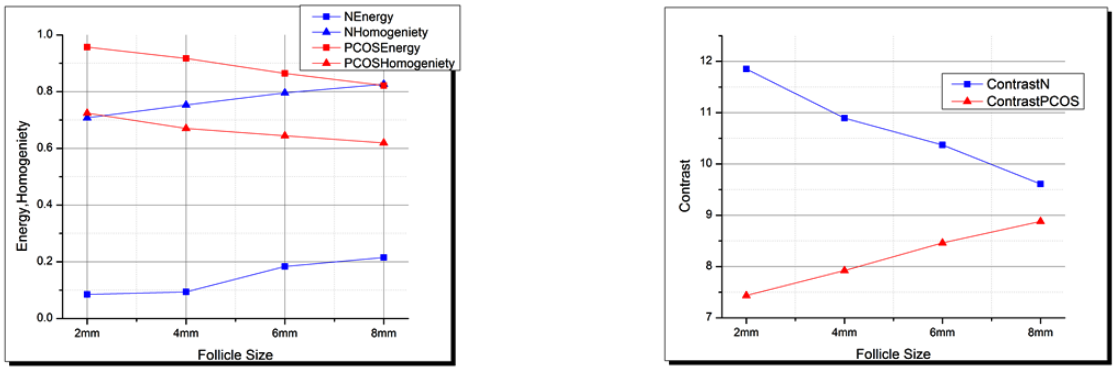

Figure 5. Contrast features in four directions; (a): Follicle wall of normal image; and (b): Follicle wall for PCOS JAMSAT

Table 4. Average texture features for 210 images in terms of follicle size (Mean±SD)

Follicle Size	Energy		Homogeneity		Contrast	
	Normal	PCOS	Normal	PCOS	Normal	PCOS
2mm²	0.078±0.03	0.697±0.09	0.766±0.12	0.755±0.09	9.891±0.21	5.782±0.14
4mm²	0.098±0.02	0.431±0.10	0.958±0.18	0.675±0.13	8.762±0.15	5.966±0.17
6mm²	0.166±0.08	0.294±0.08	1.228±0.21	0.634±0.16	8.436±0.19	6.342±0.23
8mm²	0.241±0.10	0.221±0.10	1.341±0.23	0.546±0.18	7.893±0.23	6.871±0.28

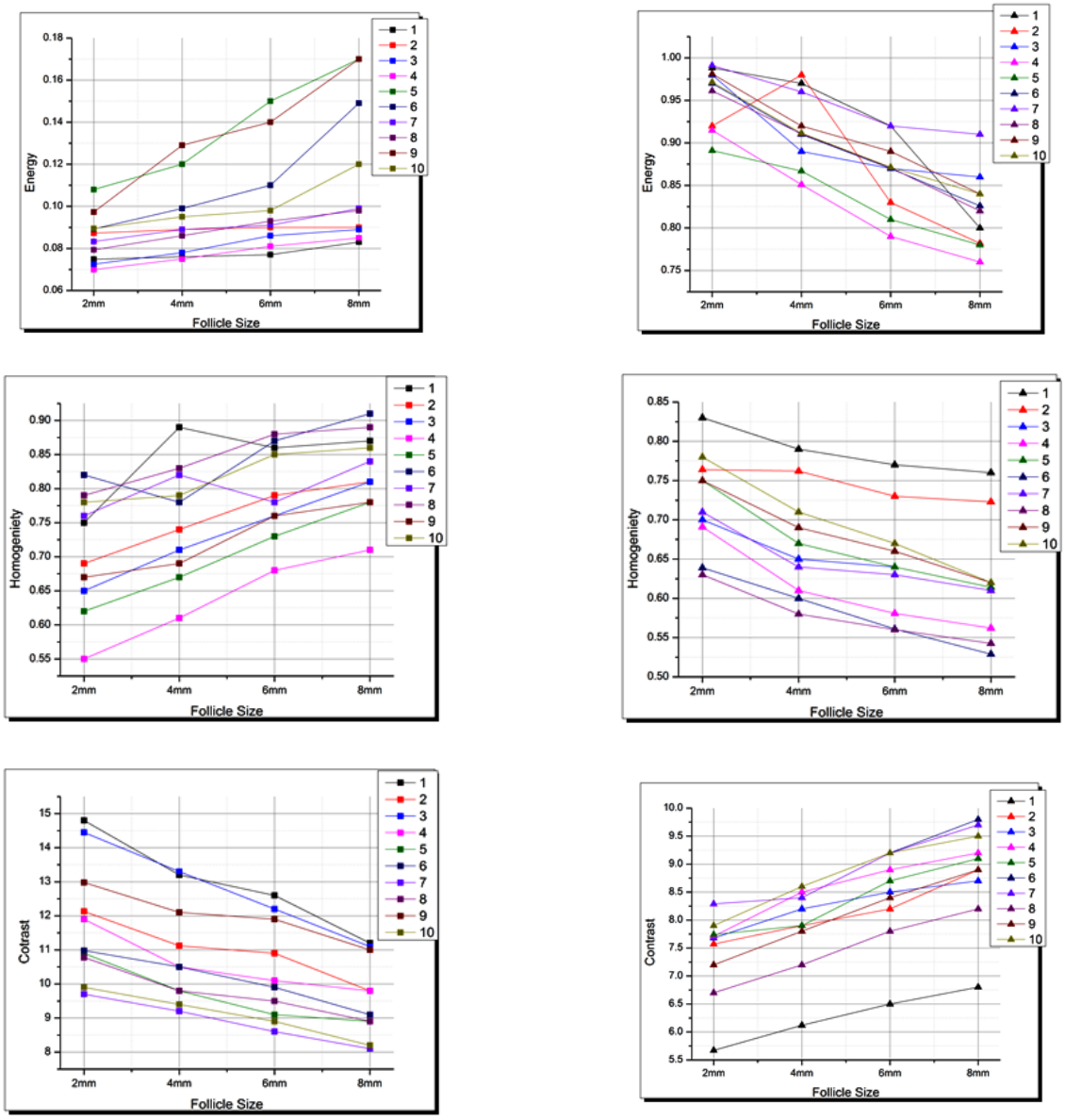

Figure 6. Features; (a): normal; and (b): PCOS

Further, the features are computed for ten images with different follicle size as shown in Figure 6. The difference in slopes between the normal and PCOS will aid in classification. The averaged values of energy, homogeneity and contrast computed for 210 images are tabulated in Table 4. The homogeneity and contrast values are high in case of normal compared to PCOS whereas energy is high in case of PCOS and low in normal.

4. Discussion

The evaluation of texture feature for normal and PCOS are obtained on day-wise images to determine the echo textures in different directions. This through light on the underlying ovarian function. Texture analysis is computed in three steps. First speckle noise is removed and followed by segmenting the follicle walls. Finally to analyze the follicle boundaries, co-occurrence matrix in the directions 00, 450, 900, 1350 are obtained for energy, homogeneity and contrast.

The energy and homogeneity features have consistently higher values in the horizontal direction (the direction of 00) compared to those in the other three directions in follicle border regions. In case of contrast feature it is lower in horizontal direction. Higher energy and homogeneity with lower contrast values indicate that a small amount of local texture variations is observed in the horizontal direction of the images. This results are useful to find differences in echo textural features in normal and PCOS image. Thus the two classes of follicle could be adequately separated by a discriminator function based on the energy, contrast and homogeneity feature space.

4. Conclusion

In this paper, a new approach to analyze the follicle walls in images has been proposed. The segmentation method is applied to the despeckled images to extract follicle wall. The follicle walls are analyzed by texture feature in all the directions (00, 450, 900 and 1350). The results can be employed in future studies for automatic recognition of different types of ovarian follicles and improve the classification accuracy. Finally, the work has implications for applications in understanding the physiologic status of follicles in women through non-invasive imaging technology.

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The manuscript does not have a direct financial relation with the commercial identity. The authors alone are responsible for the content and the writing of the paper.

Conflict of Interest

The authors declared no conflicts of interest.

References

[1] Stein IF, Leventhal ML. Amenorrhea associated with bilateral polycystic ovaries. American Journal of Obstetrics and Gynecology. 1935; 29(2):181–91. doi: 10.1016/s0002-9378(15)30642-6

[2] Ehrmann DA. Polycystic ovary syndrome. New England Journal of Medicine. 2005; 352(12):1223–36. doi: 10.1056/nejmra041536

[3] Jonard S. The follicular excess in polycystic ovaries, due to intra-ovarian hyperandrogenism, may be the main culprit for the follicular arrest. Human Reproduction Update. 2004; 10(2):107–17. doi: 10.1093/humupd/dmh010

[4] Salonen JT, Salonen R. Ultrasound B-mode imaging in observational studies of atherosclerotic progression. Circulation. 1993; 87(3):56-65. PMID: 8443925

[5] Krivanek A, Sonka M. Ovarian ultrasound image analysis: Follicle segmentation. IEEE Transactions on Medical Imaging. 1998; 17(6):935–44. doi: 10.1109/42.746626

[6] Sarty GE, Liang W, Sonka M, Pierson RA. Semiautomated segmentation of ovarian follicular ultrasound images using a knowledge-based algorithm. Ultrasound in Medicine & Biology. 1998; 24(1):27–42. doi: 10.1016/s0301-5629(97)00213-5

[7] Jain JK, Ota F, Mishell DR. Comparison of ovarian follicular activity during treatment with a monthly injectable contraceptive and a low-dose oral contraceptive. Contraception. 2000; 61(3):195–8. doi: 10.1016/s0010-7824(00)00098-6

[8] Kim ND, Amin V, Wilson D, Rouse G, Udpa S. Ultrasound image texture analysis for characterizing intramuscular fat content of live beef cattle. Ultrasonic Imaging. 1998; 20(3):191–205. doi: 10.1177/016173469802000304

[9] Raeth U, Schlaps D, Limberg B, Zuna I, Lorenz A, Van Kaick G, et al. Diagnostic accuracy of computerized B-scan texture analysis and conventional ultrasonography in diffuse parenchymal and malignant liver disease. Journal of Clinical Ultrasound. 1985; 13(2):87–99. doi: 10.1002/jcu.1870130203

[10] Barr LL, McCullough PJ, Ball WS JR, Krasner BH, Garra BS, Deddens JA. Quantitative sonographic feature analysis of clinical infant hypoxia: A pilot study. American Journal of Neuroradiology. 1995; 17(6):1025-31. PMID: 8791910

[11] Kumar, HP, Srinivasan S. Despeckling of polycystic ovary ultrasound images by improved total variation method. International Journal of Engineering and Technology. 2014; 6(4):1877-1884.

[12] Kumar PH, Srinivasan S. Fast automatic segmentation of polycystic ovary in ultrasound images using improved chan-vase with split-bregman optimiza-tion. Journal of Medical Imaging and Health Informatics. American Scientific Publishers. 2015; 5(1):57–62. doi: 10.1166/jmihi.2015.1355