Identifying and Classifying an Ovarian Cyst using SCBOD (Size and Count-Based Ovarian Detection) Algorithm in Ultrasound Image

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Abstract *– Polycystic ovaries are a sign of increasing infertility in the female population worldwide. An excessive number of follicle formations leads to polycystic ovarian syndromes. It affects the female reproductive cycle and leads to disorders such as cardiovascular issues, diabetes mellitus, and cancer. Calculating the number of follicles and detecting the follicle size is still challenging due to time complexity. Since the size of follicles and the greater number mislead the detection of the ovarian type in the ultrasound image. The ultrasound images contain more speckle noise, making the ovarian follicles difficult to see manually. A new convenient method is proposed for the detection of follicles and ovary classification is based on the measurement of size and the count of each follicle. In this paper, the work is divided into four steps, the first step preprocessing the ultrasound image. In the second step, the segmentation process is applied for object selection and separation process using an improved watershed algorithm. In the third step, based on the geometrical and statistical features the object is recognized by SCBOD accurately using various parameters such as size, count, mean, standard deviation, etc., Finally, an SVM classifier is used for classification to conclude the Polycystic ovary syndrome(PCOS) and Non-PCOS. This algorithm is proposed to the physician to find the ovarian follicles rapidly, which will offer accurate performance and is more effective in execution by adopting the SCBOD (Size and Count-based Object Detection) method.*

Keywords*: SVM Classifier, Polycystic ovary, shape-based Segmentation, size-based Feature Extraction, SCBOD (Size and Count-based Object Detection) method, Improved Watershed Algorithm*

1. INTRODUCTION

The ovary is one of the most important reproductive organs in the female reproductive system. It produces an ovum, which consists of follicles in the sac along with some fluids. A dominant follicle will release an oocyte at the time of fertility, when the count of follicles increases several times without the presence of an oocyte, then it is considered a polycystic ovary. The ovary can be classified based on the size and number of follicles shown in the image. Ultrasound images play a crucial role in determining whether that PCOS corresponds to the infertility problem. The ovary can be classified into three types: normal ovary, cystic ovary, and polycystic ovary. **Normal Ovary**: [4] The normal ovary consists of one or two dominant follicles or antral follicles. The size of the follicles is around 2 mm to 28mm and is considered a normal ovary. Antral follicles are said to be less than 18 mm. More than 18 mm below 28 mm are called follicles. **Cyst Ovary**: During the menstrual cycle period, an egg known as a follicle forms inside the sac. The sac opens and produces the egg for the fertility process. If the sac is not open, the fluid in the sac forms a cyst called a cystic ovary. It consists of many types. They are corpus luteum cysts, dermoid cysts, cystadenomas, endometriomas (a type of tissue that forms a cyst ovary), etc. Similarly, some symptoms appear during cyst growth, such as fainting, fever, breast tenderness.The size of the cyst grows around 20mm nearly. **Polycystic Ovary**: The size of the follicle is around 10mm with multiple follicles or collection of fluid increased in the sac that does not release the egg, then it is considered to be a Polycystic ovary. It can frequently occur due to prolong menstruation or excessive secretion of a male hormone normally. It results in infertility, type-2 diabetes, and heart disease.

Fig.1,2 & 3 represents the different types of ovaries with different numbers of follicles. The traditional prediction of follicles and classification of ovaries by physicians would be a time-consuming process. To overcome this issue, the proposed SCBOD algorithm will assist the physician to identify and measure the follicles for concluding the PCOS rapidly.The main objective of the proposal is to detect and classify the type of ovaries automatically with accurate results.

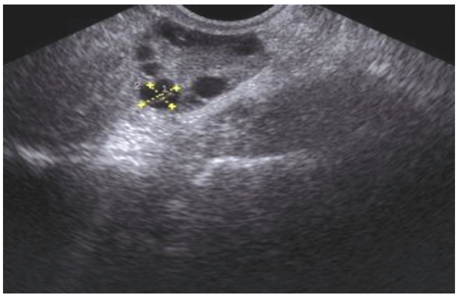


Fig. 1. Normal ovary

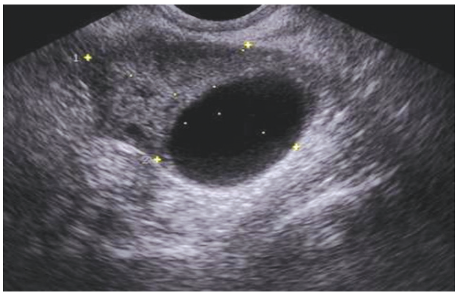


Fig. 2. Cystic ovary

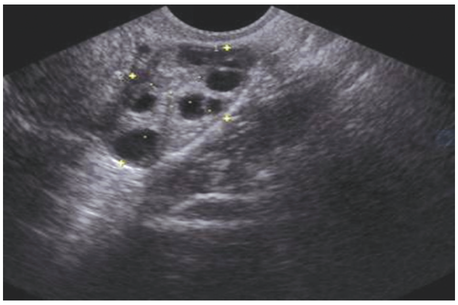


Fig. 3. Polycystic ovary

2. RELATED WORK

[1] Aiswarya et al. investigated the feasibility of noise detection in the ovary. It is still a challenge for multiple follicle counts and boundary detection for single follicles.To avoid this kind of problem, a proposal of decomposition of singular values is introduced, along with fuzzy and contour are used for segmentation. [2,22] Hiremath &Froyman examine PCOM(Polycystic ovarian morphology) criteria to detect the PCOS, PCOM describe the presence of the count and size of the follicle like more than 12 follicles with 2-9mm in size, based on this criteria diagnosis of PCOS concluded.[3] P.S.Hiremath et al, reviewed the geometrical parameter calculation to detect the follicle. The main reason for using minor axis length and major axis length parameters is to estimate the follicle region effortlessly. Gaussian low filtering morphology process, edge-based segmentation help to improve the follicle detection properly in the proposed algorithm [5] Angelos et al. indicated that ovarian number detection could be found in a few seconds using preprocessing techniques and segmentation process with a watershed method. However, these methods are prone to biasing the reporter. Automated concepts would help to make the final decision and increase efficiency, statistical power, and quality by generating the methods. [6] Ranjitha et al, explained the automated system method for finding follicles based on object growing, including different stages. She implemented the speckle noise reduction in the images using median filters, Watershed algorithm is used for follicle extraction. This makes it easier for segmentation sessions. [7]Bhagya et al, reviewed four different approaches to find out the leukemic cell present in the blood. They are edge-based segmentation, canny edge detection, clustering-based segmentation, and morphological watershed-based segmentation. These methods concluded better approaches for performance along with parameters like precision, accuracy, and sensitivity. [8]Eliyani et al, used watershed techniques for follicle detection along with preprocessing techniques for speckle noise removing and follicle segmentation process executed with active contour without edge detection method.[9]Sandy Rihana et al, used preprocessing Morphological techniques for noise reduction, horizontal and vertical line scan threshold implement for further processing, then fusing the binary image for classification to removing the unused area, later the SVM classifier is performed for a classification task.[10]Rose T et al, proposed the follicle monitoring is an essential tool for physicians to diagnose PCOS issues, follicle detection is found using the active contour method with preprocessing techniques. The distance regularized level set used to manage the follicles boundary limits, watershed segmentation also utilized.

[11] Prema T et al proposed the watershed method and Region-based Active contour used for the segmentation process, and classification has been performed based on the geometric features like area, compactness, circularity along with K-NN classifier to detect the follicle in ovary images. [12]Dorin et al used watershed algorithm, active contour model, Gaussian filtering to regularized level set for segmentation process and detect follicle in binary mode ultrasound images. Frechet distance, Error area rate as considered for quality parameters to finding follicles.[13] Mahdi et al investigate regarding shape-based segmentation in three dimensional abdominal ultrasound images using

probabilistic kidney shape based method and confirm the result superiority for segmentation.[14] Hayder et al implemented different classification methods for image classification. The SVM and CNN play a vital role in it. Based on the results concluded the best classifier is the SVM classifier.The results are given according to the image type in this article.[15] Yinhui et al, suggest morphological filtering to preprocess, modify the labeled watershed algorithm for segmentation, a cluster-based method with different criteria was processed for extracting the follicle cysts from the ovary images.

[16] Jun Liu et al, Proposed a fully automated algorithm for object detection using MCL Concepts(Multiple Concentric Layer) which is one of the criteria to find out the focal region of the follicle in the ovary. They processed three different stages as image preprocessing, detection of the focal region of the follicle, and MCL(Multiple Concentric layers) ; these criteria results are compared with the edge-based segmentation for the follicle detection process.

[17] Carmina et al, Proposed the performance of SVM(Support Vector Method) and CNN(Convolution Neural Network) for tumor detection. The result obtained based on the accuracy and minimal data set feature grade the better result with the SVM method. Since difficulty in finding the follicle's cysts may lead to a problem of efficiency, reliability, and variability. This proposed automated method will overcome all these issues by detecting the follicle in the ultrasound image and counting could be more complicated. In this work, the proposed automated system SCBOD applied the size and count-based detection and separation of the follicle cysts, then the target is extracted by using an improved watershed algorithm. Finally, the classification has been examined using the SVM classifier method.

3. DATASET

The dataset has been collected according to the guidelines of expertdoctors from the Athiran Scan's center, and Diagnostics. The total number of images used in the proposed system is 100 images. They are 40 normal ovary images,40 polycystic ovary images, and 20 cystic ovary images. Distributed dataset for classification as in tab.(1). The pixel size of eachimage used in the proposed system are 300px by 300px.

Table1. Dataset Distribution for Classification

Different types of ovary	Training	Testing
Normal ovary(40)	30	10
Cystic(20)	15	5
Polycystic(40)	30	10

4. METHODOLOGY

In the Proposed system SCBOD consist of 4 different phase for identifying the follicle in the ovary ultrasound image, and then ovarian classification was executed based on the different types of ovaries. Some of the criteria used to detect the follicle are the size and count of the follicle with geometrical features. Different phase as follows,

1. Pre-processing
2. Size Based Automated Segmentation process using improved Watershed method.
3. Size and Count Based Object Recognition and Feature Extraction (Object Detection, Separation, and Calculation) using Geometrical features.
4. Classification of Ovary using SVM Classifier.

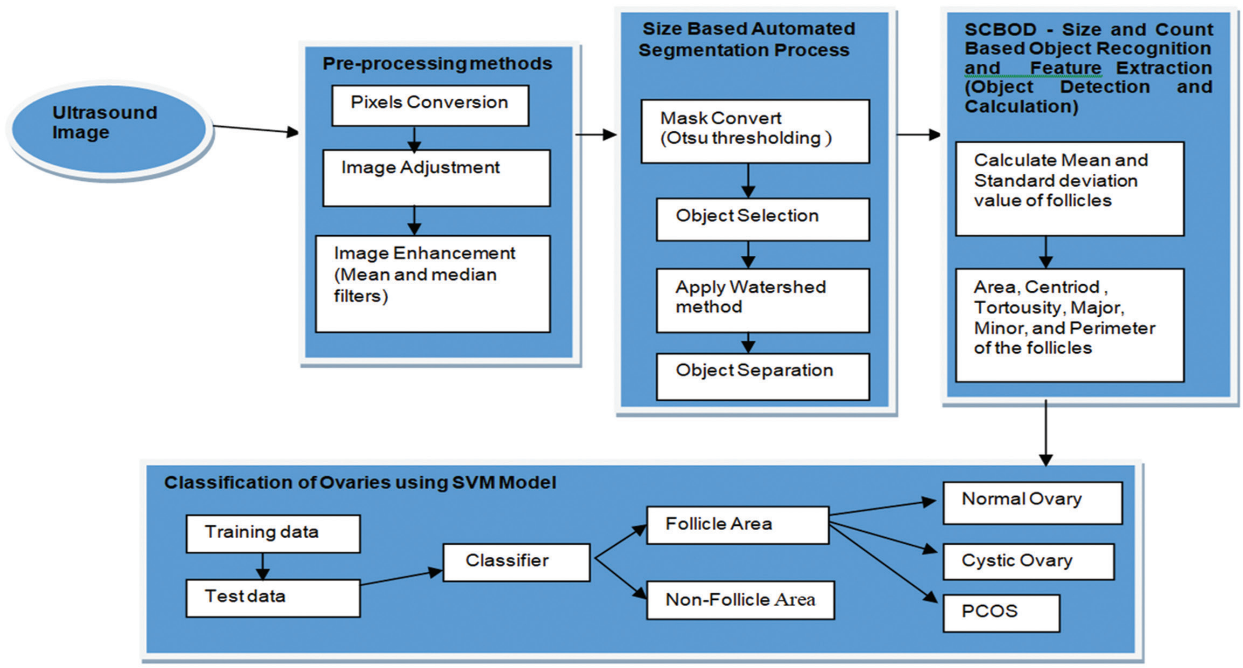


Fig. 4. Framework for the Proposed Algorithms

Fig. 4 represent the proposed algorithm to detect the follicle with preprocessing techniques like Image Adjustment and Image Enhancement, then Segmentation has been done using Mask Convert, object selection done with advanced watershed algorithm and object detection is concluded along with calculating follicle value according to the parameter like Area A, Centroid C, Tortousity Tt, Major Ma, Minor Mi, and Perimeter P. Based on this value finding the follicle region or non-follicle region. Finally, the follicle is classified using an SVM classifier to find out the PCOS or Non-PCOS.

The algorithm for the proposed system is as follows,

Step 1: The pre-processing method has been performed using image pixel conversion, image adjustment, and Image enhancement to reduce the speckle noise reduction process.

Step 2: Size-based Automated segmentation process done by using mask convert, object selection based on shape, normally the ovarian shape is considered oval and sphere, and object separation has been done using the improved watershed method using local maxima.

Step 3: SCBOD algorithm is applied for object detection and feature extraction. Object Detection and Calculation are performed by the size of the follicle. This can be compared based on the ground value of each size of the follicle as, a normal ovary with 8-10 follicles around 2 mm to 28mm in size, cyst 50 to 60 mm(3 to 4 inches), for Polycystic 12 to more follicles exist with 9mm diameter in size. Here the object detection is examined by size and count of follicles using some geometrical features its is shown in tab 1.

Step 4: Finally the SVM classifier is used for the classification process to determine the PCOS or Non-PCOS ovary.

Pseudocode:

Pre-processing method:

1. *To read the input image(L) from the dataset D.*
2. *resize the image by using pixel convert as size_pix =(300,300)*
3. *Save the regenerated image after pixel conversion as a new one R.*
4. *then, apply the brightness and Contrast to the saved image.*

   If (b!=0) & (b>255) then apply brightnessvalue = 255
5. *finally apply the mean and median filter to remove noise and find the intensities of pixels which are presented in the center of image.*

4.1. SIZE BASED AUTOMATED SEGMENTATION PROCESS USING IMPROVED WATERSHED METHOD

Segmentation is the process of dividing the images or partitioning the image into many regions. Different types of segmentation can be done based on the need of image processing.In this phase segmentation, After Applied preprocessing methods to the image and convert the image using mask convert techniques with Otsu threshold value (used for image segmentation also known as binarization). The mask converts the image before the segmentation process to select the object using the edge detection method. Finally Apply the improved watershed algorithms, now some lines appear at the image look as superimposed in the original image Fig. 7. and Fig 8. Fig. 11 represents the object selection and watershed algorithm process.

4.1.1. Mask Convert

Mask Convert implies the inverting image in binary masks whereas white represents 0 and black value 255, Threshold value has to be set automatically according to the image. Otsu threshold is used to reduce the gravy level in binary images. After the mask conversion Morphology operation Open, Close, and Dilate, Erode smoothes the objects and removes the small holes and isolated pixels.

4.1.2. Object Selection

During the mask convert all the follicle boundaries close to each other and look like a single object, to overcome this kind of problem. Separating the object is another task in this segmentation process, watershed transformation is used to separate the object, before that edge detection is applied to highlight the sharp difference in the intensity in the selected image, and Maxima is used to find out the segment with one particle be maximum.

4.1.3. Improved Watershed Algorithm and Object Selection and Separation.

The Watershed method is mainly used for object separation from the neighbor images. Watershed lines form at the minimum regions [19]. This is the reason why it's more sensitive with local minimums. To overcome this issue local maximum is implemented (which is opposed to a local minimum) so that it can be separated from the objects along with watershed algorithms. Some of the steps follow in this proposed system by applying watershed algorithms to avoid the over-segmentation issues (finding the edge and applying the watershed algorithm) as follows.

The following pseudo code represents steps involved in the segmentation process.

Pseudocode:

Size and Shape based Automated algorithm:

Mask Convert is used for binarization of image and applied OTSU threshold to detect the optimal threshold value of the pixels.

Set T(threshold value as 0 at beginning), because OTSU threshold method will compute the threshold value automatically.

6. *Input image(L),Ts the size of OSTU threshold,Tos temp object selection, Td object detection*
   1. *for each image (I) to L*
   2. *extrate the set of object region Ro*
   3. *for each object o in Ro*
   4. *if size(o)<Ts*
   5. *remove o from Ro*
   6. *else increase the object selection region to select next.*
3. *After object selection applying the watershed algorithm.*
   1. *After the object selection region, Find the foreground, background region .*
   2. *Generate the local minima of the distance between each object in the foreground. Maxima objects are obtained in the background(opposite).*
   3. *For background used morphological operations and foreground using distance transform.*
4. *Apply improved watershed segmentation algorithm. SU_bg=Surebackground, su_fg=Sureforeground, unk_region=unknowregion, pointer=unknown region*
   1. *Background extraction using morphological operation(dilation and opening for detecting the su_bg)*
   2. *Foreground extraction using distance transformation maximum(for detecting su_bg).*
   3. *Finding the unknown area(unk_region) by subtracting the su_bg and su_fg .*
   4. *Apply watershed algorithm by marking the su_bg != 1 and unk_region =0*
   5. *If (su_bg ! = 1)*
      then pointer= pointer + 1
      else
      if (unk_region=0)
      then pointer[unk_region == 255] =0
      if(b_region = -1)
      then inputimage(pointer == -1) = (255,0,0)
   6. *The output image with watershed segmentation.(represented in fig.11).*

Fig.11 represents the object selection and improved watershed algorithm process using Regional maxima by opening and closing construction filters.(which is used more efficiently and effectively as normal standard open and close operation. This can give the overall shape of image without disturbance.

Fig. 5.



Fig. 6.

Fig. 5. Bit Conversion
Fig. 6. Image Enhancement

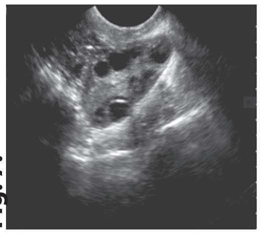
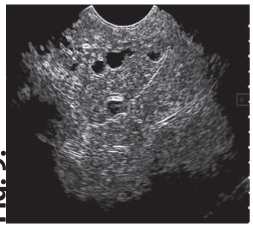
Fig. 7.



Fig. 8.

Fig. 7. Original image
Fig. 8. Mask Convert

Fig. 9.


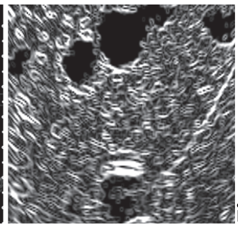


Fig. 10.

Fig. 9. Object Detection
Fig. 10. Maximum object with edge

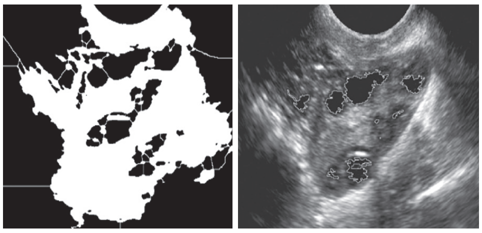


Fig. 11. Object selection using improved Watershed object separation

4.2. SIZE AND COUNT BASED OBJECT RECOGNITION AND FEATURE EXTRACTION(OBJECT DETECTION SEPARATION AND CALCULATION) USING GEOMETRICAL FEATURES

The geometric and statistical operations play an important role in image processing by measuring the objects in ultrasound images. Identification of cysts is diagnosed by calculating the size of follicles under certain limitations [9]. Measuring the follicles is the major concept for extraction. It is required regularly to examine the analysis. Some of the geometrical parameters are used to extract the objects like Area A, Centroid C, Tortuosity Tt, Major and Minor Ma, and Perimeter P, and calculate the parameters of interest to create a new database with this data which is explained in the Table 3.

The parameters used to measure the cyst are in the following manner.

- ***Area A is used*** to calculate the number of pixels inside the most possible follicles.
- ***Major-axis length(a, b)***, gives the pixel distance between the major-axis endpoint of the segmented area.

Major-axis length(Ma)= $\sqrt{(a_2 - a_1)^2 + (b_2 - b_1)^2}$ (1)

- ***Minor-axis length (a, b)***, gives the pixel distance between the minor-axis endpoint of segmented area.

$$\textit{Minor-axis length(Ma)} = \sqrt{(a_2 - a_1)^2 + (b_2 - b_1)^2} \quad (2)$$

The major and minor axis represents the ellipse shape at the central moment of the follicle segmented area, because all the cysts or follicle in the shape of oval, its around elliptic one.

- ***Centroid C***, is used to measure the center of the object in the follicle ROI(region of interest) it estimates ROI measure by using the a and b coordinates.

$$\textit{Centroid C}=(C_a+C_b) \quad (3)$$

- ***Tortuosity Tt*** is used to estimate the arc-chord which will give the ratio of curve length(C) and its distance of end length (L) of the estimated follicles.

$$\textit{Tortuosity Tt} = C/L \quad (4)$$

- Perimeter is considered as several pixels in the boundary of the follicles.
  suppose if (a_1……a_n) is the boundary list, then

$$\textit{Perimeter P} = \sum_{j=1}^{N-1} d_j = \sum_{j=1}^{N-1} |a_i - a_{i+1} a_{i+1}| \quad (5)$$

Table 2. Standard follicle size and count of ovaries based on OM(Ovary Morphology) and optimized segmentation output along with the count of follicle detection

Different Ovary types	Size of follicles in px(pixel)	Count of follicles	Optimized segmentation image for a different ovary with different counts and sizes of the follicle	Number of follicle present and detected
Normal Ovary	15px-10000px	1-18		Presented 5 Predicated 4
Cystic Ovary	4200px-75000px	1-2		Presented 1 Predicated 1
PCOS	15px-9000px	12-20		Presented 11 Predicated 10

4.3. CLASSIFICATION OF THE OVARY USING SVM CLASSIFIER

Here the main objective for using the geometrical features is to estimate the calculation of the follicle region because the follicle shapes under circular shape or oval in shapes. Based on this feature the dataset is divided into two types are training and testing datasets. The Mean value(Area, Centroid, Tortousity Tt, Major, and Minor, and Perimeter, and the Standard Deviation values(Area, Centroid C, Tortuosity Tt, Major Ma, Minor Mi, and Perimeter σP) are utilized for detecting the follicle region based on the classification rules PCOM(Polycystic Ovarian Morphology).

4.3.1 Training Phase and Testing phase

In the training phase, the proposed geometrical feature to calculate the size and count of the follicles using the parameter as Area A, Centroid C, Tortousity Tt, Major Ma, Minor Mi, and Perimeter P for finding follicle region during the ultrasound image based on the medical export suggestion and saved for the reference for benchmark calculation. In the testing phase, applied all the geometrical features in the input image to find the segment follicle region and implemented the SVM classification for finding follicle region or non-follicle region.

An SVM classifier is used to classify the ovary into 3 main categories: normal ovary, cystic ovary, and polycystic ovary also compared with the benchmark data for proper classification results.The standard size and count of ovaries fall under the following norms as shown in tab.1.[20]The SVM is the most efficient method for supervised classification models including many probabilistic classifiers. SVM is more popular and easily scalable for a large data set. During the testing phase, these are the parameter that plays a vital role to determine the follicle size and count in the ovarian image and SVM classifier implemented to examine the ovary types as normal ovary, cystic ovary, and polycystic ovary.[21] SVM kernel function is the most important function used to implement the input vector to higher dimensional feature spaces. Polynomial kernel used in the proposed algorithm, which is commonly used by kernels in SVM, and this can satisfy Mercer's condition that can be used for space theory of random processes.

The performance of statistical information of image classification using SVM classifier is listed in Table 2. By precision value, it can be determined the predicate value is accurate. If the precision value of false positive pixels are high. This will give the ratio of true positive to the sum of true positive and false positive. The recall will show all correctly classified instances in the testing phase. F-measure combines both properties of precision and recall as a single measure. These are the parameters used for evaluating the performance of the algorithm. Table 3 shows the confusion matrix for testing performance. While testing phase 39 images are classified as PCOS correctly, 58 images classified as Non-PCOS correctly, only one image as classified incorrectly, this will give 2% wrong prediction from the entire dataset. Total accuracy prediction is 94% from the entire dataset.

5. RESULTS AND DISCUSSIONS:

100 images have been used to determine the ovary types, in that 75 images phase used training and 25 images used for testing phase. Ten-fold cross-validation is used for the testing phase to build a model for the

testing process. based on the size and count of follicle classification of the ovary is examined. In 100 instances there are 40 polycystic ovaries, 20 cystic ovaries, and 40 normal ovaries used, the SVM classifier classified 94% accuracy. Cross verification of accuracy is also executed using the confusion matrix referred to in Tab.6. Similarly Table 5 represents the summary value for the classification validation. Since the database has fewer images will predicate this above accuracy.

$$Accuracy = \frac{TP+TN}{TP+FP+TN+FN} \tag{6}$$

$$Precision = \frac{TP}{TP+FP} \tag{7}$$

$$Recall = \frac{TP}{TP+FN} \tag{8}$$

$$F-Measure = \frac{2*(Recall*Precision)}{(Recall+Precision)} \tag{9}$$

$$MCC = \frac{(TP*TN)-(FN*FP)}{\sqrt{(TP+FN)(TP+FP)(TN+FN)(TN+FP)}} \tag{10}$$

Table 3. Automated measurement of Different follicles with Geometric Feature Extraction.

Geometrical Feature Extraction	Normal ovary	Cystic ovary	PCOS
Area	27	88	42
Perimeter	26.401	87.367	40.792
Major Axis Length	1.128	2.257	3.169
Minor Axis Length	1.128	1.128	6.653
Mean	48.881	6.653	32.498
Standard deviation	22.542	10.113	9.754

In the future, planning to collect different datasets to get better execution and accuracy levels and [4] include some standard error metric features like dice and jaccard for maintain the time complexity. To evaluate the performance of classification Accuracy, Precision, Recall and M-Measure are implemented. they are as follows in Table 4.

Table 4. Performance of SVM classifier during the testing phase

Class	TP Rate	FP Rate	Precision	Recall	F-Measure
PCOS	0.950	0.000	1.000	0.950	0.974
CYST	0.850	0.038	0.909	0.850	0.850
Normal	0.975	0.050	1.000	0.975	0.951
Weighted Avg	0.940	0.028	0.985	0.940	0.940

Table 5. Summary for Cross-validation during Classification of Ovary

Method	Mean Absolute Error	Root Mean Squared Error	Relative Absolute Error	Root Relative Squared Error	Accuracy
SVM Classifier	0.2378%	0.2994%	55.6544%	64.8167%	94%

Table 6. Confusion Matrix of Classification during testing phase

Ovary type	A(PCOS)	B(CYST)	C(NORMAL)
PCOS	38	2	0
CYST	0	17	3
NORMAL	0	1	39

6. CONCLUSION AND FUTURE WORK:

In this paper, the proposed SCBOD algorithm is used to implement the optimized segmentation, feature extraction, and classification of the ultrasound ovary images. The detection and selection are made by the size and count of the follicle, which falls within the ovary image. Based on essential geometrical features and SVM classifer the classification done, the ovary is classified as normal, cystic, and polycystic. The proposed method is capable of detecting PCOS in a short time which can reduce the burden of the physicians to determine PCOS detection difficulty. The proposed method improved the accuracy results by obtaining 94% with good efficiency. Still, there is more confusion about finding the normal cyst and other cysts like endometrioma cysts. In the future, we will keep improving the work to determine the ovary types and give more accuracy to the classification of the ovary, which can be executed by increasing the dataset size for better results and complexity.

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