Improving the Prediction and Classification of PCOS using SCBOD Feature Extraction with Augmentation

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Summary
To implement the proposed rule-based algorithm SCBOD(Size and Count based object detection algorithm with augmentation) in ultrasound images for finding the PCOS(Poly Cystic Ovary Syndromes) also known as Poly Cystic Ovary Disease in the ovary. It exists with the symptoms and signs of androgen excess and abnormal ovarian functions which leads to failure of the ovulation process. PCOS is a common hormonal change disorder that affects the endocrine system in the female reproductive system. It causes multi-genetic disorders including environmental influence, food habits, and other life-threatening issues. A new emerging trending technique is used to analyze the ultrasound images to recognize the different types of ovaries like Normal ovary, Cystic ovary, and PCOS. An improved novel SCBOD architecture is implemented to identify the ovary and classify the ovaries as polycystic ovaries or non-polycystic ovaries. In this paper, the work is divided into three methods, I. Ovary can detection and classification using CNN method with augmentation, II. Proposed SCBOD feature extraction and classification with SVM classifier, and III. Augmentation techniques with SCBOD feature extraction and Classification with SVM classifier. The proposed algorithm gives more accuracy when augmented the dataset and all the other methods by increasing the time complexity and performance, which are evaluated using geometrical, statistical, and other metrics. The pathologist can able to detect PCOS accurately with the help of the proposed novel SCBOD algorithm.
Keywords:
PCOS (Polycystic Ovarian Syndrome), SCBOD (Size and Count Based Object Detection), Augmentation techniques, SVM classifier, CNN classification, Watershed method.

1. Introduction

Polycystic ovary syndrome is also called an imbalanced hormonal disorder that affects the female reproductive system.[1] PCOS was first proposed by Stein and Leventhal in the year of 1935. Because of PCOS women's reproductive can be affected in the ratio of (5-20%) of the worldwide women population. This hormonal disorder may cause the risk and signs of pre-puberty and postmen-pause time. Infertility is one of the main side effects of PCOS formation, also face acne for adults, excess amount of hair growth in the face and body, increased weight gain, pelvic pain, diabetes, heart disease, etc. [2] PCOS causes serious health problems in women, it should be found at an earlier age to prevent women from infertility and other side effects of breaking diseases as mentioned previously. [3] The criteria for detecting PCOS are that at least one ovary has a volume of 10 cm3 or more, or that there are more than 12 follicles with a diameter of 2-9 mm. Ovary plays a vital role in the human reproductive cycle. [4] Diagnosing PCOS is not a complicated process, the main requirement for diagnosis is a standardized application need. Diagnosisof PCOS is often delayed, which may cause further issues. It has undergone many stages, beginning in the prenatal period(including the development of the embryo egg) and ending with menopause. Also, it secretes various kinds of hormones.. This hormonal imbalance leads to PCOS. All eggs are originally contained in the ovary in a single layer of cells called a follicle, which supports the egg. Fig1 represents the Ovary image with follicles. These eggs mature throughout time, and one is eventually discharged from the ovary during each menstrual cycle. According to the results of the ovarian analysis, the ovary is categorized into one of the three categories of ovaries normal ovary, cystic ovary, or polycystic ovary.

A normal Ovary with dominant follicles consists of 2.5cm to 5cm in length, 0.6cm to 1.5cm in thickness, and 1.5cm to 3cm in width. Antral follicles are those that are less than 18mm in size, whereas dominant follicles are those that are more than 18mm in size. Dominant follicles are developed as ovulation follicles. Ovulation happens 36 hours following the production of a hormone called luteinizing hormone, which is secreted by the pituitary gland[5]. Fig.2 represents the Normal ovary with dominant follicles.A cystic ovary is filled with fluid packets or sacs on the ovary surface. It consists of a single cyst with a larger size compared to the normal follicle size[6]. Fig.3 represents the cystic ovary image.A polycystic ovary consists of more than 12 follicles in count that are smaller than 9mm in size[7]. Women affected by PCO do not get regular periods and get infertility issues.Fig.4 represents the polycystic ovary image.

To avoid this situation detecting the PCOS at starting stage with the help of our proposed novel SCBOD algorithm. The dataset executes along with CNN classification, the second stage is implemented with an

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SCBOD feature extraction SVM classifier, and finally, the augmentation examine with the SCBOD feature extraction and SVM classifier.In the proposed novel algorithm the PCOS is detected in the early stage with high efficiency.

Fig. 1 Ovary Image

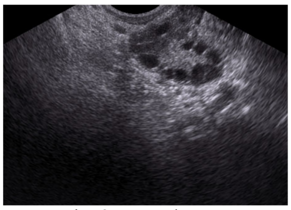


Fig. 2 Normal Ovary

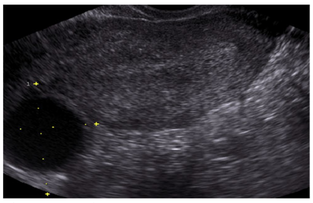


Fig. 3 Cystic Ovary

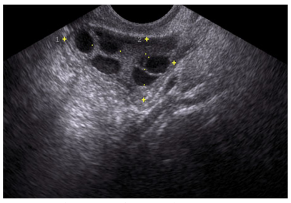


Fig.4 Polycystic Ovary

2. Related works:

[8] Dewi et al. classify the ultrasound image using CNN(Competitive Neural Network) with the combined action of Hemming Net, and Max Net before classification feature extraction has been done using Garbor Wavelet Calculation. The final result found with CNN is 80.84% using 60.64-second process timing, weight 0.03, and bias0.002.[9] Purnama et al. Classified ultrasound images using three different machine learning approaches: KNN using Euclidian distance, SVM classifier, and Neutral Network-LVQ. To obtain a binary image, the dataset image was preprocessed with a low pass filter, morphology operations, histogram average, binarization of images, and edge detection. The image's features were extracted manually using the Gabor Wavelet before the classification process. The final best results were obtained 82.55 % with using SVM is used and 78.81%.[10] Dan represents the fast CNN implementation of GPU(Graphical Processing Units) to develop the deep hierarchical architecture for classification using Benchmark dataset NORB, CIFAR10, and MINST. [11] Cahyono et al. performed the CNN for the classification of ovary images as PCO class and non-PCO class and achieved an average score of about 76.36% with five-fold cross-validation. [12] Diego et al. proposed the different CNN detectors for detecting the ovarian structure and comparing the CNN result with other computer vision methods successfully.[13] Isha extracted 15 features that were retrieved from the follicle candidates using an active contour algorithm after it was applied to the B-mode pictures. The best features were then chosen to feed into a multilayer perceptron neural network using particle swarm optimization (PSO). [14] Abu et al. used SVM(Support Vector Machine) for image classification descriptor. Final accuracy was obtained at 86.90%.[15] Amsy et al. discussed the detection and prediction of PCOS. Classification of ovary implemented by using different machine learning techniques such as Principle Component Analysis(PCA), Naïve Bayes classifier,logistic regression,KNN(K-Nearest-neighbor, CART (Classification and Regression Tree), SVM(Support Vector Machine), Random Forest Classifier with the final accuracy 89.02% for PCOS prediction.[16]Jyothi explained automated ovarian classification using an SVM classifier. The contourlet transform method was used for preprocessing and active contours were applied for segmentation and the best accuracy obtained was 98.89%. [17] Maciej Kusy proposed the Support Vector Method and Sequential Minimal Optimization for ovarian cancer classification problems.[18] Madhumitha et al. approached different machine learning operations as hybrid methods along with preprocessing. The combination of SVM, KNN, and Logistic Regression algorithmsobtained an accuracy of 98%. [19] Gopalakrishnan et alused ultrasound images of the ovary, assess the key factor and methods of PCOS detection.

Although several algorithms have been developed for detecting and classifying PCOS and non-PCOS. However, the success of this strategy largely rests on the accumulation of hands-on expertise in recognizing the different kinds of ovarian anomalies shown in their associated ultrasound images.Because of this, novice ultrasound operators constantly struggle to distinguish between various cyst types, which ultimately results in a reduced rate of accurate diagnosis.Inexperienced operators need to be provided with supporting tools to help boost their diagnostic accuracyotherwise lead to major issues.To overcome this kind of problem the proposed systemSCBOD is the most effective method for determining the follicle detection and classification of cyst types.

2.1 Challenges in detection and classification of PCOS:

According to survey the challenges for classification and identification are 1.Collection of huge dataset is big issues for medical diagnose in image processing system, 2.Images is not perfectly illuminated because of noise. In the ultrasound images, the noise percentage is more compared with other images, the fluid present in the image consider as speckle noise. So while acquisition processing the noise also consider as follicles or cysts and this leads to miss diagnosis. 3.Classification may suffer with class similarity and variety like normal, cystic, and pcod. Still, it's an anomaly to conclude the cystic or normal variation of ovary images.

3. Methodology:

3.1 Image augmentation

It is the most emerging technique for the imaging process to replicate the image count based on the fewer existing image. It will increase more data sets of databases artificially without including external data. It can able to expand the data availability more for training sessions, this may lead to avoiding the inadequate dataset images for research during the classification of images and other processing. Different types of augmentation taxonomy are available, and some of them are indexed in the following table.2.

The rotation augmentation technique is used generically for rotating the image without changing the information. The flip augmentation is like same as the rotation augmentation techniques, this will flip the image both vertical and horizontal, up and down, and right and left. Using noise augmentation, the noise is add to the image. To learn more robustness to change the images and focus on manipulating values shown in the pixel for reducing the difference between the neighbouring pixel. Zooming will help to resize the image to conclude the pixel value properly or used to insert the pixel values for better visibility. The cropping method will help to select the correct position of the image.

When a dataset is trained by machine learning the corresponding parameters are adjusted as per the defined input and output. The motive to build the training model is to get best results without less loss percentage, and the dataset size should be more. But in this case, the images are not enough to complete the task and time complexity. Hence getting more images to augment is the best way to increase the dataset for training the images. Since the images have some minor changes in them, like flipping images, rotating, adding noise to the images, etc. which show in table.2.[20] Augmentation can reduce the time complexity for data collection drastically, hence it is proven in the performance of pre-trained models and gradually reduced the overfitting issues. The traditional transformations methods were applied for all the images before preprocessing , for each input images the transformations is applied and created the more data for a single input image as 1:9. referred in below Fig. 5.

Pseudocode: Image Augmentation
Input: An ovary ultrasound image: Data € Dataset
Output: An Augmented Dataset Model : Model
Start
Augdata = Ovary images(Dataset)
Training(Tn), Validation(V),Testing(T) = DataSplitup(dataset)
for i.. 1 to Tn do
Augdata1 = Random Rotation
Augdata2 = Vertical and Horizontal Flip
Augdata3 = Scaling
Augdata4 = Noise
Augdata5 = Cropping
Augdata6 = Padding
Tn = Add(Training(Tn),Augdata1,Augdata2,Augdata3,Augdata4,Augdata5,Augdata6)
DataAugmentation = (Tn, new)
Model=TnModel (DataAugmentation, Validation)
Model Eval(Model)
Return Model

3.2 Dataset for detection and classification of ovaries

The dataset was collected under the recommendations of professional doctors from the Athiran Scan and Diagnostics facility. The suggested system employs a total count of 100 images for the age group of 25 to 40. There are 20 images of normal ovarian, 40 images of polycystic ovaries, and 40 images of cystic ovaries. The distribution of dataset images for classification is shown in table.1. Increased dataset after using augmentation are replicated in the ratio 1:9 which will reduce the time complexity of seeking more datsets

Table.1 Distribution of Dataset with and without Augmentation method for processing.

Types of Ovaries	Normal ovary(20)	Cystic ovary(40)	Polycystic ovary(40)	Total no. of Images
Training phase without Augmentation	15	35	35	85
Testing phase without Augmentation	5	5	5	15
Type of ovaries images count after augmentation	135	315	315	765
Training phase with Augmentation	130	310	310	750
Testing phase with Augmentation	5	5	5	15

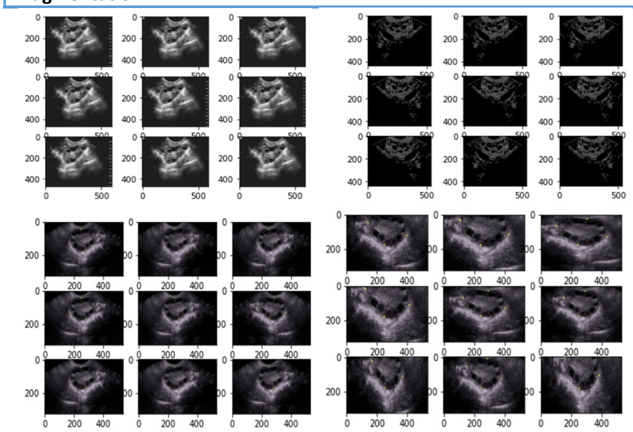
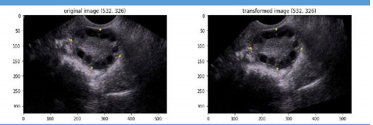
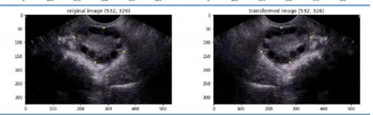
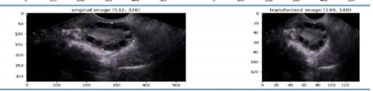
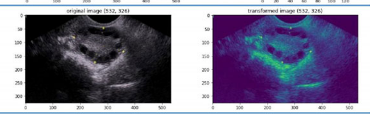
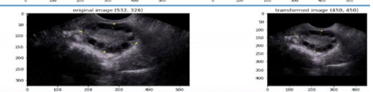
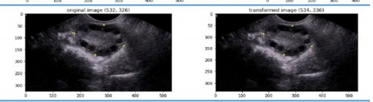
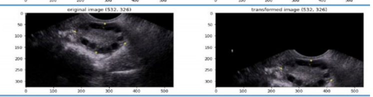


Fig. 5 Represent Augmentation of different 4 images with different augmentation techniques in the 1:9 ratio.

Table.2 Different types of DA(Data Augmentation with example)

Index	Name of Augmentation (Position Augmentation)	Function	Conversion of original images with different augmentation of ovary images from database.
1.	Random Rotation	The image is rotated randomly	
2.	Vertical and Horizontal Flip	The images is flipped either vertical or horizontal	
3.	Zoom or scaling or Resizing	Resize the give images	
4.	Noise	Adding some blur effect to the image.	
5.	Cropping	The image position is selected	
6	Padding	The image is pad with left ,right, bottom and top	
7.	Translation	The is transform at any valued position	

3.3 Proposed System for detection and classification of ovary

The proposed work includes the feature extractions which conclude classification of the ovary either PCOS or non-PCOS with the best accuracy level. It consists of image acquisition using augmentation, preprocessing, segmentation, feature extraction, and classification.In the proposed architecture the workflow is divided into three different phases as mentioned in Fig.6. below.

I. Automated Feature Extraction CNN method with Augmentation techniques,
II. Proposed SCBOD Feature Extraction Algorithm using SVM classifier without Augmentation techniques.
III. Augmentation techniques with SCBOD Feature Extraction Algorithm and Classification with SVM classifier.

3.4 Image Proprocessing for training and testing dataset:

Once the augmentation is completed the images are separated for the preprocessing. In preprocessing the noise reduction process is most important, because the ultrasound images contain more speckle noises. This will affect the pixel's quality of the images and it's said to be multiplicative noise in the ultrasound images which will degrade the quality of images. The ultrasound image of the ovary contains a more fluid-like substance which will be producing more noise, this can be considered as speckle noise in ovary ultrasound images. Next image contras is implemented using mask converted to avoid the low quality of the image, this will increase the differentiate foreground and background features in the images for better analysis. In this Median filters are used to enhance the images while noise removing process.

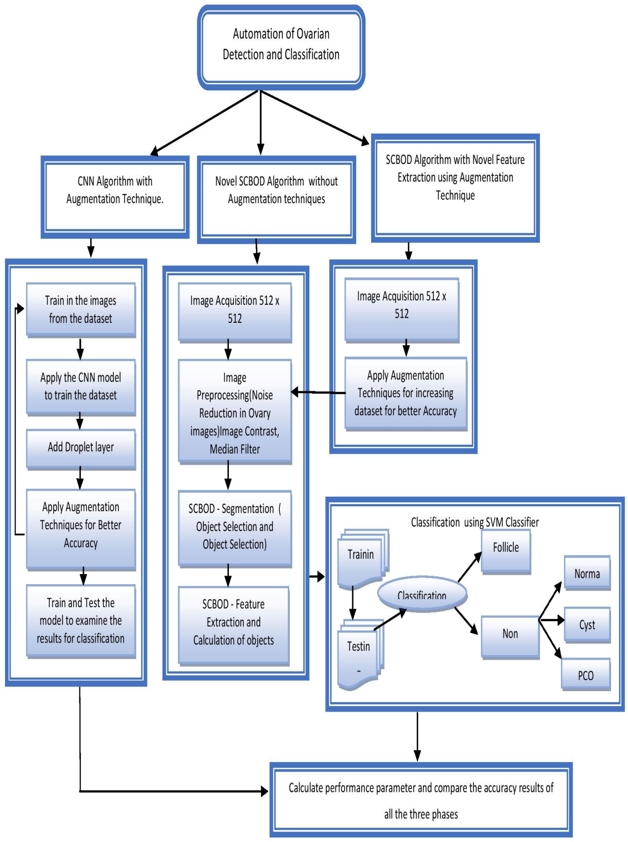


Fig.6.Architecture diagram for Proposed System.

3.5 Segmentation process(watershed, threshold)

After preprocessing the image segmentation for follicle detection and classification are enhanced, then the SCBOD algorithm is applied to the minima and maxima region.finding the follicle region with the help of maxima threshold detects the minima region. At the end applying the watershed algorithm to the output image of maxima and minima , this will separate the follicle region finely. Based on the geometrical and statistical parameters the follicle size and count is calculated

4 Automation Feature Extraction CNN method and Augmentation techniques

CNN (Convolution Neural Network) is used for extracting the image content in detail. CNN analyses the original pixel data from the image to train the model, and then automatically extracts the features for improved classification. A dataset that has been labeled by a professional. The datasets are organized into three categories: training data (75%), validation data (10%), and testing data (15%) with the combined combination of different ovaries as normal, cystic, and PCOS. The CNN model of the proposed system consists of a combination of input layers, hidden layers, dense layer and output layers.

Algorithm 1: (Phase I)

1.Input the images from the dataset for the phase 1 execution.
2.Compute the CNN2d model along with different layers. (The system has different layers like two convolution2D layers, two max-pooling layers, two fully connected layers, and a dense layer.)
3. Finally, the output is calculated accurately based on CNN2d.
4. Apply the testing process to the model to analyze the classification output.
5. Since the accuracy result is less because of the less dataset.
6. Apply the Augmentation techniques to improve the accuracy value and increase the dataset.
7. Repeat step: 6 and compare the output of Step: 4 and Step: 6 for best accuracy.

5. II. Feature Extraction novel SCBOD detection of follicles(geometrical and statistical) and classification with SVM classifier

In phase II proposed SCBOD algorithm is implemented in the original datasets. This alogrithm mainly concentrates on follicle detection and classifying the different ovaries based on follicle count and size. It contains geometrical and statistical features to identify the extract count and the size of follicles.These parameter are shown in the below table.

Algorithm 2: (Phase II)
1. Image Acquisition as made from the dataset properly.
2.Preprocessing of the image using noise reduction for less speckle noise in that median filter and image contrast applied to extract the features in the images.
3.In the Segmentation process, a watershed algorithm and Otsu's threshold are applied for object selection and detection.
4.Feature extraction has been computed using SCBOD and calculated the object value using statistical and geometrical methods.
5. SVM classifier is used for classification of the ovary.
6.Evaluate the accuracy results obtained from step:5.

After detection of the follicle region the novel SCBOD is applied for feature extraction. So this SCBOD contain geometrical and statistical parameter to identify the follicle size and count. The equations(1) to (12) are used to implement the pcos detection, its shown in the table. 3.

5.1 SVM Classifier

The classification is the completion stage to conclude images into different desired categories. In the proposed system classification has been done by using SVM classifier(Support vector machine) algorithm.[23] This classification provide the optimal results using hyperplane of class while classification even the number of parameters is less and it gives lowest error rate on the validation dataset.
Training Phase: At the most of features extracted and train the classifier for classification process.Input the image for classification processing, before classification all necessary process has compute which mention in the Algorithm phase(II). Uses all the geometrical to evaluate the follicle region including the follicle size and count respectively. Polynomial kernel is used.
Testing Phase: At testing phase all the extracted features are determined and the SVM classifier is implemented for the classification of ovary is normal, cystic and PCOS.

1: Input the ovary image after preprocessing.
2: Extract all the necessary features for each follicle region
3: Select all the optimal extracted features and stored using the classifier.
4: Train the stored feature and test for it.
5: Process can be repeated for all images to implement the better results.

6. SCBOD Algorithm with Novel Feature Extraction using Augmentation techniques.

In phase III, after the image acquisition dataset process for data augmentation techniques to reduce the data acquisition time and increase the capacity of data for preprocessing, segmentation, and classification.
Algorithm 3:(Phase III)
1. Image acquisition and preprocessing of the ultrasound ovary image using image pixel conversion, image adjustment, and applying a few more filters for speckle noise reduction.

2. After preprocessing apply augmentation to the images. Using augmentation techniques, to avoid insufficient images for a training session and prevent overfitting issues.
3.The segmentation process executed based on the size with mask conversion and watershed techniques is applied for object selection and separation process accurately.
4.Classification has been done by using geometrical and statistical feature extraction of the proposed algorithm SCBOD along with the SVM classifier.
5.The results were obtained and saved for further process.
6.Repeated step 2 Again step 3 and 4 were repeated to obtain the results.
7.Compare the final results obtained from steps 5 and 6 to get a better accuracy level.

7. Results and Discussion

The results proposed algorithm SCBOD for follicle detection and classification are discussed in this section, different ultrasound ovary images were used to evaluate the PCOS detection. The obtained result is 88 and 94.3% only in phases I and II. Based on this procedure planning to increase the dataset count by using the augmentation techniques and implementing a novel SCBOD algorithm with an SVM classifier. The dataset has multiplied more comparatively before image count. Then we classify the images with the new updated expanded dataset with all necessary performance parameters. Now the new result was obtained with the accuracy of 96% in the phase III SCBOD Algorithm. Hence it provided performance evaluation for classification based on parameters like accuracy, sensitivity, confusion matrix, and specificity. All the metrics values are calculated and shown in the table. 3,6,and 7. The results from the table suggest that the proposed method performs better than the other conventional algorithms reliably for detecting and classifying ovaries and differentiating the performance with different metrics as shown in Fig.7 and comparison made with existing work of other authors table.4. Confusion matrix comparison has been done for all the 3 phases below table.5.

Table 3 Sample measurement for ovary follicle

S.No	Type	Area	Mean	StdDev	Min	Max	Perimeter	Major	Minor	Median
1	PCO	45	25.228	11.916	20.441	66.333	44.283	0	0	21.899
2	PCO	42	32.498	9.754	21.393	64.333	40.792	0	0	20.599
3	Normal	34	19.605	7.543	3.479	30.72	33.242	0	0	22.666
4	Normal	38	33.861	26.196	1.663	89	37.483	0	0	22.657
5	Normal	35	33.668	10.122	19.813	64.333	33.838	0	0	31.108
6	Cyst	54	66.536	16.323	47.011	110.438	53.488	0	0	62.129
7	Cyst	59	93.085	28.127	59.903	151.217	58.412	0	0	81.945

Table.4 Compare the result with other author work

S.No	Author and method	Results obtained
1.	B.cahyono et al. CNN method	76.36%
2.	Prema.T et al. knn classifier	80%
3.	Amay et al. SVM classifier	82.92%

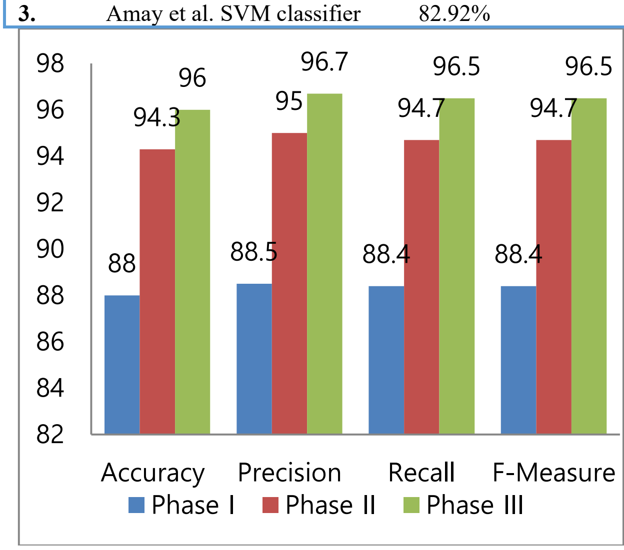


Fig.7 Represented the performance comparison of different phases.

Table 5 Confusion Matrix for Phase I, II & III Algorithm

Algorithm	Phase I			Phase II			Phase III		
Class	A(PCO)	B(cyst)	C(normal)	A(PCO)	B(cyst)	C(normal)	A(PCO)	B(cyst)	C(normal)
PCO	288	27	0	38	2	0	294	21	0
CYST	20	266	9	0	17	3	0	306	5
NORMAL	0	15	109	0	0	39	0	0	124
Accuracy	88.4%				94.3%			96%	

Table.6 Parameter used for calculation and result verification.

S,No	Parameters	Explanation	Equations
1.	Mean	Images have different intensity values normally, this can be predicted by using the Mean parameter. It indicates the intensity values of image pixels in the same area[21].	Mean = $\frac{1}{N}\sum_{R=1}^{N} Intensity(R)$
2.	Standard Deviation	It represents the intensity and gray level difference in the images[22].	SD= $\frac{1}{N}\sum_{R-1}^{N}(Mean(R) - Intensity(R))^2$
3.	Area	It is used to calculate area of the follicle pixel in the ovary.	A = 100
4,	Major-axis length and Minor-axis length	Used to specify the scalar value in pixel to represent the follicle major axis and minor axis	*Major-axis length(Ma)* $= \sqrt{(a_2 - a_1)^2 + (b_2 - b_1)^2}$ *Minor-axis length(Ma)* $= \sqrt{(a_2 - a_1)^2 + (b_2 - b_1)^2}$
5.	Eccentricity	Its can used to calculate distance between the ratio of follicle and the major axis length as value in between 0 to 1, which represented the measurement table.2.	E= c/a
6.	Diameter	Scalar measurement used to specify the diameter of the follicle. Also other measurements like centorid, tortuosity, perimeter etc,. are used to calculate the accurate value for each follicle.	D = 2r
7,	Accuracy	To conclude the measurement of actual result of the proposed SDBOD algorithm	$Accuracy = \frac{TP+TN}{TP+FP+TN+FN} x\ 100\%$
8.	Sensitivity	It give how mach positive values has been measured and also gives the probability ratio for right test.	$Sensitivity = \frac{TP}{(TP+FN)}$
9.	Specificity	Used to find the optimum value.	$Specificity = \frac{TN}{(TN+FP)}$
10.	Recall	Imbalance classification can be achieved by recall parameter	$Recall = \frac{TN}{FN+TN}$
11.	Precision	It shows how much the predicted value of the out put is correct,	$Precision = \frac{TN}{FN+TN}$
12.	F1 Score	Used to measure the accuracy while testing phase.	$F1\ Score = \frac{2 * Precision * Recall}{Precision+Recall}$

Table 7 Performance value comparison obtained for PhaseI,II & II Algorithm

Algorithms	Phase I (CNN with Augmentation Technique)				Phase II (SCBOD Algorithm without Augmentation Technique)				Phase III (SCBOD Algorithm with Augmentation Technique)			
Metric/Class type	**Normal**	**Cyst**	**PCO**	**Wt.Avg**	**Normal**	**Cyst**	**PCO**	**Wt.Avg**	**Normal**	**Cyst**	**PCO**	**Wt.Avg**
TP Rate	0.879	0.971	0.914	0.884	0.984	0.971	0.908	0.947	1.000	0.984	0.933	0.965
FP Rate	0.040	0.071	0.046	0.066	0.014	0.071	0.000	0.032	0.008	0.048	0.000	0.021
Precision	0.813	0.907	0.935	0.885	0.931	0.907	1.000	0.950	0.961	0.936	1.000	0.967
Recall	0.879	0.855	0.914	0.884	0.984	0.971	0.908	0.947	1.000	0.984	0.933	0.965
F-Measure	0.845	0.859	0.952	0.884	0.957	0.938	0.952	0.947	0.980	0.959	0.966	0.965
MCC	0.814	0.761	0.871	0.884	0.949	0.893	0.932	0.915	0.977	0.930	0.944	0.965
ROC	0.920	0.880	0.934	0.816	0.992	0.950	0.977	0.968	0.943	0.996	0.983	0.943
Area	0.735	0.799	0.891	0.909	0.926	0.893	0.962	0.927	0.961	0.927	0.972	0.979
Accuracy obtained	**88.4%**				**94.3%**				**96%**			

8. Conclusion:

Classification of the ovarian images using CNN and SVM is difficult to represent the PCO or Non-PCO class, even though extraction of feature has been done automatic and manually both of the system obtain a better accuracy results. The SVM classifier with augmentation results conform the superiority of the proposed SCBOD algorithm comparing to the CNN with augmentation techniques. In future work increasing the dataset and parameter for detection and feature extraction will give better performance results in classification.

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