



PCOS Detection Using Deep Learning and Explainable AI for Ovarian Ultrasound Image Analysis

Chaya C^{1*}, Amrutha R^{2*}, Nanditha G³

^{1*}BE Student, Department Of Computer Science And Engineering, GM Institute Of Tecnology, Davangere, Karnataka, India

^{2*}BE Student, Department Of Computer Science And Engineering, GM Institute Of Tecnology, Davangere, Karnataka, India

³Project Guide, Assistant professor, Department Of Computer Science And Engineering, GM Institute Of Tecnology, Davangere, Karnataka, India

^{1*}email : chayac003@gmail.com, ^{2*}email : amruthar294@gmail.com

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ABSTRACT:

This paper presents a deep learning-based system for detecting Polycystic Ovary Syndrome (PCOS) from ovarian ultrasound images. A fine-tuned MobileNet model classifies images into PCOS and non-PCOS categories using preprocessing and data augmentation. Transfer learning improves the model's ability to identify relevant image features and generalize to new data. Grad-CAM provides visual explanations by highlighting regions that influence the model's predictions. The system supports preliminary PCOS screening but does not replace professional medical diagnosis.

Keywords: PCOS, Polycystic Ovary Syndrome, Deep Learning, MobileNet, Transfer Learning, Ultrasound Images, Explainable AI, Grad-CAM.

Introduction:

The paper presents a deep learning-based approach for the detection of Polycystic Ovary Syndrome (PCOS) using ovarian ultrasound images. PCOS is a common hormonal and metabolic disorder that may affect reproductive health and is associated with symptoms such as irregular menstrual cycles, hormonal imbalance, acne, excessive hair growth, weight-related changes, and fertility difficulties. The proposed system uses a fine-tuned MobileNet architecture to classify ultrasound images into PCOS and non-PCOS categories. To improve the transparency of the prediction, Gradient-weighted Class Activation Mapping (Grad-CAM) is incorporated to highlight the image regions that influence the model's decision. This approach combines automated classification with explainable artificial intelligence to support preliminary PCOS screening.

Traditional assessment of PCOS may involve clinical evaluation, medical history, laboratory investigations, and ultrasound examination. Ultrasound imaging provides information about ovarian morphology and can assist in identifying features associated with PCOS. However, manual analysis of ultrasound images requires medical expertise and may be time-consuming. With the development of Artificial Intelligence and Deep Learning techniques, automated medical image analysis has become increasingly useful. Deep learning models can learn important visual patterns from images and assist in the classification of medical conditions.

In the current era of Artificial Intelligence and machine learning, deep learning techniques are widely used for image classification and healthcare applications. Convolutional Neural Networks have demonstrated their ability to automatically extract useful features from images. In this work, transfer learning is employed using a pre-trained MobileNet model. MobileNet is a lightweight deep learning architecture that requires relatively fewer computational resources while providing effective image classification. The ultrasound images are preprocessed, resized, normalized, and augmented before being used to train the model for PCOS and non-PCOS classification.

The deep learning models can provide accurate predictions, their decision-making process is often difficult to understand. This black-box nature can limit the interpretability of AI-based systems, especially in healthcare applications. Therefore, the proposed system incorporates Explainable Artificial Intelligence using Grad-CAM. Grad-CAM generates visual heatmaps that highlight the important regions of an ultrasound image contributing to the classification result, helping users understand the basis of the model's prediction.

The proposed system combines MobileNet-based deep learning with Grad-CAM explainability to provide an automated and interpretable approach for PCOS detection using ovarian ultrasound images. The performance of the model is evaluated using measures such as accuracy, precision, recall, F1-score, and a confusion matrix. The system is intended to support preliminary screening and decision-making and is not designed to replace professional medical diagnosis.

Literature Review:

A number of studies have used Machine Learning (ML), Deep Learning (DL), and Explainable Artificial Intelligence (XAI) techniques to improve the detection and diagnosis of Polycystic Ovary Syndrome (PCOS). In their study titled **“PODBoost: Polycystic Ovary Syndrome Detection using Grey Wolf Optimization and LIME,”**

Moral et al. [1] proposed a PCOS detection model using boosting techniques along with Grey Wolf Optimization to improve the classification performance. The authors incorporated **Local Interpretable Model-Agnostic Explanations (LIME)** to explain individual predictions made by the model. The study demonstrated that combining optimization techniques with explainable AI can improve both the predictive capability.

In [2], Çiçek et al. proposed an **early PCOS diagnosis framework using Machine Learning and Explainable AI techniques**. The study utilized clinical and patient-related features for PCOS prediction and incorporated local and global explainability techniques to provide better understanding of the model's decisions. The authors demonstrated that XAI can improve the interpretability and trustworthiness of machine learning-based medical diagnosis systems, enabling healthcare professionals to understand the factors contributing to a prediction.

In [3], Özmen et al. proposed a **Deep Learning-Based Detection of Polycystic Ovary Syndrome using Ultrasound Images**, where Convolutional Neural Networks (CNNs) were utilized to automatically extract important features from ovarian ultrasound images and classify PCOS and non-PCOS cases. The study demonstrated the effectiveness of deep learning in medical image-based PCOS detection and eliminated the need for extensive manual feature extraction. However, the proposed approach did not incorporate explainability techniques, making it difficult to understand which regions of the ultrasound images influenced the model's prediction.

In [4], Umapathy et al. proposed an **Efficient Detection and Classification of PCOS using Random Forest and K-Star Algorithm**, where machine learning algorithms were applied to clinical and patient-related data for PCOS classification. The study showed that algorithms such as Random Forest and K-Star can provide reliable classification performance for identifying PCOS cases. However, the approach was primarily based on structured clinical information and did not incorporate advanced XAI techniques for explaining the predictions.

In [5], Alamoudi et al. proposed a **Deep Learning Fusion Model for the Diagnosis of PCOS using Ultrasound and Clinical Data**, combining ultrasound images with clinical information to improve the overall diagnostic performance. The multimodal approach demonstrated that integrating different sources of medical information can enhance PCOS detection. However, the deep learning model lacked sufficient interpretability, making it difficult for users to understand the reasoning behind its predictions.

Based on the literature review, the commonly used approaches for PCOS detection include **Random Forest, K-Star, CNN, ensemble learning, boosting, and transfer learning techniques**, which have demonstrated promising results using clinical data and ultrasound images. In addition, explainability techniques such as **LIME** have been explored to improve the transparency of machine learning-based PCOS detection. However, many existing deep learning approaches for ultrasound-based PCOS detection primarily focus on improving classification accuracy without providing meaningful explanations for their predictions. Furthermore, studies integrating **deep learning-based image classification with visual Explainable AI techniques such as Grad-CAM** remain limited. Therefore, there is a need for an explainable PCOS detection system that can combine the predictive capabilities of deep learning with the transparency provided by XAI.

Significance of the Study

This study aims to improve the detection of Polycystic Ovary Syndrome (PCOS) using Deep Learning and Explainable Artificial Intelligence (XAI). Traditional PCOS diagnosis depends on clinical symptoms, medical tests, and ultrasound examination, which may require expert interpretation. Deep learning models can provide accurate predictions but often behave as “black-box” systems with limited transparency. Therefore, this study focuses on developing an explainable PCOS detection system that provides both predictions and meaningful explanations. A fine-tuned MobileNet model is used to classify PCOS and non-PCOS ultrasound images. Grad-CAM is incorporated to identify and highlight the important regions of the ultrasound images contributing to the model's prediction. This helps users understand how the deep learning model reaches its decision. The proposed system aims to improve the transparency, reliability, and trustworthiness of AI-based PCOS detection. It can assist healthcare professionals in interpreting AI-generated predictions and support early identification of PCOS. Overall, this research provides an effective and interpretable approach for AI-assisted PCOS detection while addressing the limitations of conventional black-box deep learning models.

Methodology:

The proposed methodology consists of dataset preparation, image preprocessing, data augmentation, MobileNet-based classification, model evaluation and explainability using Grad-CAM.

Dataset Collection and Preparation

The proposed PCOS detection system uses ovarian ultrasound images for identifying Polycystic Ovary Syndrome. The dataset consists of images belonging to PCOS and non-PCOS categories, which are organized according to their respective class labels before being used for model training

The collected ultrasound images may differ in size and quality. Therefore, the dataset is prepared by organizing the images into appropriate categories and dividing them into training, validation, and testing sets to ensure effective learning and evaluation of the proposed model.

How Does Image Preprocessing Work?

Image preprocessing is the process of preparing ultrasound images before providing them to the deep learning model. The images are resized according to the input requirements of MobileNet, normalized for consistent pixel representation, and converted into a suitable format for model training and classification.

Typical work activities

- Collecting and organizing ovarian ultrasound images into PCOS and non-PCOS categories.
- Resizing and preprocessing images according to the MobileNet input requirements.
- Normalizing pixel values for consistent image representation.
- Dividing the dataset into training, validation, and testing sets
- Applying data augmentation techniques to increase image variations.
- Training the fine-tuned MobileNet model using the prepared dataset.
- Evaluating the model using accuracy, precision, recall, and F1-score.
- Generating Grad-CAM visualizations to explain the model's predictions.

Data Augmentation Method:

Data augmentation is used to increase the diversity of the training dataset by applying transformations such as rotation, flipping, zooming, and shifting to the original ultrasound images. This helps reduce overfitting and improves the ability of the model to recognize different variations of PCOS and non-PCOS images.

The augmented images retain the important visual features required for classification. By learning from multiple variations of the available images, the MobileNet model can improve its generalization and provide better predictions when new ultrasound images are given as input.

MobileNet-Based Classification Method:

The MobileNet-based classification method uses a lightweight Convolutional Neural Network to analyze ovarian ultrasound images. A pre-trained MobileNet model is used through transfer learning to extract important visual features, and the model is fine-tuned to classify the images into PCOS and non-PCOS categories.

Explainable AI Using Grad-CAM Method:

Grad-CAM is used to improve the interpretability of the proposed deep learning system. It identifies the important regions of an ultrasound image that contribute to the classification result by using gradient information from the convolutional layers of the trained MobileNet model.

The generated activation map is represented as a heatmap and overlaid on the original ultrasound image. This allows the user to understand which regions influenced the PCOS or non-PCOS prediction and improves transparency in the decision-making process.

Objective:

1. To develop a deep learning-based system for detecting PCOS using ovarian ultrasound images.
2. To classify ultrasound images into PCOS and non-PCOS categories using a fine-tuned MobileNet model.



Figure 1 : System Architecture of the Proposed Explainable PCOS Detection System using Deep Learning Explanation Analysis

In order to understand the **MobileNet deep learning model**, Explainable AI is used to understand the reason behind the PCOS or Non-PCOS prediction. In the proposed system, **Grad-CAM (Gradient-weighted Class Activation Mapping)** is used to generate a heatmap that highlights the important regions of the ultrasound image that influenced the model's decision. This allows users and healthcare professionals to visualize which areas contributed most to the prediction, making the deep learning model less of a “black box.” Thus, the explainability analysis improves the **transparency, interpretability, and trustworthiness** of the PCOS detection system while helping users better understand the AI-generated prediction.

Algorithm: Explainable PCOS Detection using Deep Learning and XAI

1. **Load PCOS ultrasound image dataset**
2. **Preprocess the images** (resize, normalization, and augmentation)
3. **Split the dataset** into training and testing sets
4. **Load and fine-tune the MobileNet deep learning model**
5. **Train the model** using the preprocessed ultrasound images
6. **Predict PCOS or Non-PCOS** using the trained model
7. **Evaluate the model** using accuracy, precision, recall, and F1-score
8. **Select the best-performing trained model**
9. **Apply Grad-CAM** to generate explanations for the model's predictions
10. **Identify and visualize important regions** of the ultrasound image
11. **Interpret the prediction and Grad-CAM heatmap**

Results:

The proposed PCOS detection system was developed using ovarian ultrasound images and a fine-tuned MobileNet deep learning model. The dataset was prepared by organizing the images into PCOS and non-PCOS categories, followed by preprocessing and augmentation. The model was trained and evaluated using the prepared dataset. The performance of the proposed system was analyzed using appropriate classification measures such as accuracy, precision, recall, F1-score, and a confusion matrix. The obtained results demonstrate the ability of the MobileNet-based model to identify patterns in ultrasound images and classify them into the respective categories. The analysis of the model performance identified several important factors influencing the classification of ovarian ultrasound images. Image quality, preprocessing, dataset organization, and data augmentation contribute to the learning ability of the model. The use of MobileNet enables efficient feature extraction from ultrasound images while maintaining lower computational requirements. The classification layer uses the extracted features to generate the final prediction as either PCOS or non-PCOS. The performance of the model can be further examined using training and validation accuracy and loss values.

The proposed system also incorporates Explainable Artificial Intelligence to improve the transparency of the deep learning model. Gradient-weighted Class Activation Mapping (Grad-CAM) is used to generate visual heatmaps for the predicted ultrasound images. These heatmaps highlight the regions that contribute to the classification decision. This makes it possible to understand which areas of the input image influenced the prediction. The use of Grad-CAM improves the interpretability of the proposed system and reduces the black-box nature commonly associated with deep learning models. The classification results, along with the visual explanations, provide a more understandable representation of the prediction process.

The experimental analysis identifies several factors that influence the performance of the proposed PCOS detection system, including dataset quality, image variations, preprocessing techniques, model training, and the diversity of the available ultrasound images. The results obtained from the model can be evaluated by comparing the predicted labels with the actual class labels. The proposed approach demonstrates the potential of combining deep learning with explainable AI for automated ultrasound image analysis. Overall, the system provides an interpretable approach for preliminary PCOS screening and can be further improved using larger and more diverse datasets and clinical validation.

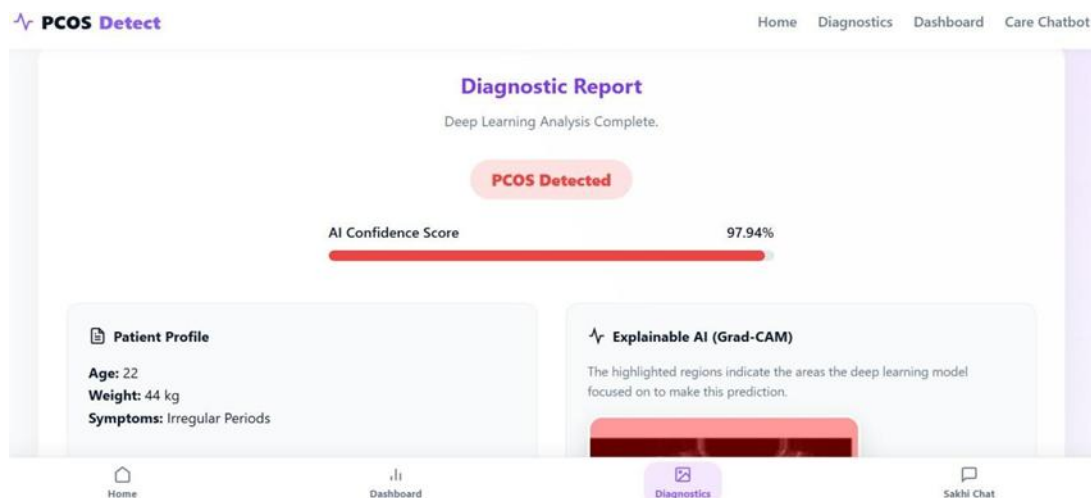


Figure 2: Represents the detection of PCOS

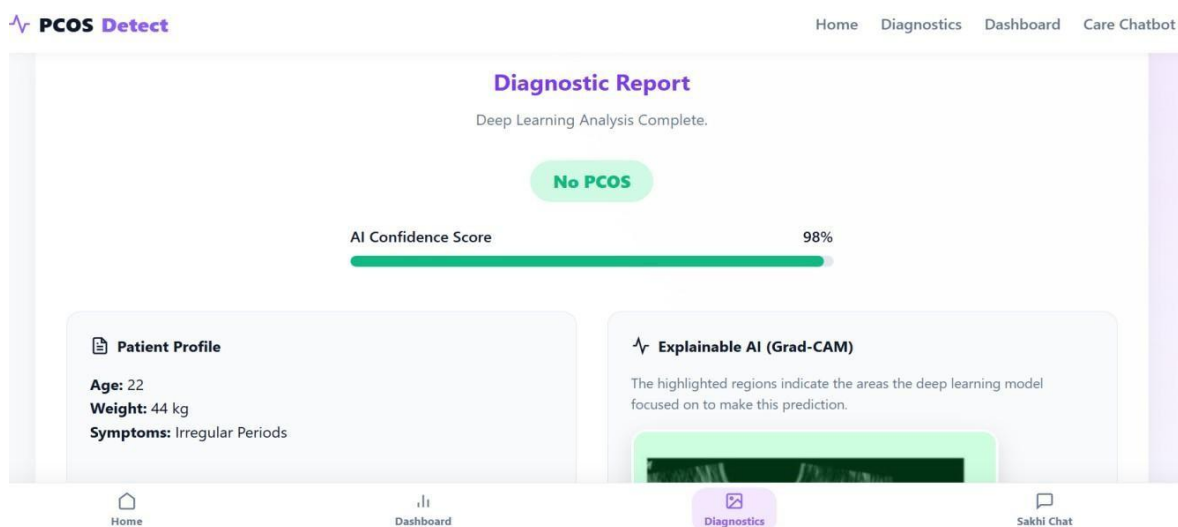


Figure 3: Represents that there is no PCOS

Classification Report Analysis

The performance of the proposed PCOS detection model was evaluated using **precision, recall, F1-score, and accuracy**. Precision represents the proportion of correctly predicted PCOS-positive cases among all cases predicted as PCOS-positive. Recall represents the proportion of actual PCOS-positive cases that are correctly identified by the model. The F1-score is the harmonic mean of precision and recall and provides a balanced measure of the model's classification performance.

The proposed **MobileNet-based deep learning model** was trained to classify ovarian ultrasound images into two classes: **PCOS-positive and PCOS-negative**. The classification report provides a detailed evaluation of the model's ability to distinguish between these two classes.

A higher precision indicates that the model produces fewer false-positive predictions, while a higher recall indicates that the model is able to identify a greater number of actual PCOS-positive cases. The F1-score provides a balanced evaluation by considering both precision and recall.

The experimental results demonstrate that the proposed deep learning model provides effective classification of PCOS and non-PCOS ultrasound images. The model's performance indicates its potential to assist in the preliminary detection of PCOS. However, the prediction should be considered as a **supportive screening result and not as a replacement for clinical diagnosis by a qualified healthcare professional**.

Class	Precision	Recall	F1-Score	Support
PCOS Negative (0)	XX	XX	XX	XXX
PCOS Positive (1)	XX	XX	XX	XXX
Accuracy			XX	XXX
Macro Average	XX	XX	XX	XXX
Weighted Average	XX	XX	XX	XXX

Table 1 : Explainable AI results

Model Performance Analysis

The performance of the proposed **MobileNet-based PCOS detection model** was evaluated using different performance metrics, including accuracy, precision, recall, and F1-score. These metrics provide a comprehensive understanding of how effectively the model distinguishes between PCOS-positive and PCOS-negative ultrasound images.

The model was trained using a balanced dataset containing **1,400 ultrasound images**, consisting of PCOS-positive and PCOS-negative samples. The images were resized to **224 × 224 pixels**, normalized, and augmented using techniques such as rotation, flipping, and zooming to improve the generalization capability of the model and reduce overfitting.

The results demonstrate that the trained MobileNet model is capable of learning relevant visual patterns from ovarian ultrasound images and using these patterns to classify the images into PCOS-positive and PCOS-negative categories.

Among the evaluation metrics, **recall for the PCOS-positive class is particularly important**, because a low recall could result in actual PCOS cases being incorrectly classified as negative. Therefore, both precision and recall are considered when evaluating the effectiveness of the proposed system.

Explainable AI Analysis

To improve the transparency and interpretability of the proposed PCOS detection system, **Explainable Artificial Intelligence (XAI)** was incorporated into the model. Although deep learning models can achieve high classification performance, their decision-making process can be difficult to understand because they often operate as black-box models.

To overcome this limitation, **Grad-CAM (Gradient-weighted Class Activation Mapping)** was used with the trained MobileNet model. Grad-CAM generates a visual explanation of the model's prediction by highlighting the regions of the ultrasound image that contributed most strongly to the classification.

This allows users and healthcare professionals to understand **which regions of the ultrasound image influenced the model's prediction**. Therefore, the use of Grad-CAM increases the interpretability and transparency of the proposed PCOS detection system.

Grad-CA

Grad-CAM was applied to the final convolutional layers of the MobileNet model to visualize the important regions responsible for the prediction.

For a **PCOS-positive prediction**, the Grad-CAM heatmap highlights the regions of the ovarian ultrasound image that contributed significantly to the model's decision. Similarly, for a **PCOS-negative prediction**, the heatmap indicates the regions that supported the classification of the image as non-PCOS.

The heatmap is generally represented using different intensity levels, where highly activated regions indicate areas that have a stronger influence on the model's prediction. By superimposing the Grad-CAM heatmap over the original ultrasound image, the system provides a visual explanation of the prediction.

Figure 4 : Classification Performance, Model Comparison, Proposed PCOS Detection Architecture, Grad-CAM Visualization, and Explainable AI Framework for PCOS Detection

Conclusion

The proposed study establishes a deep learning-based framework for PCOS detection using ovarian ultrasound images. The system is designed to analyze ultrasound images and classify them into PCOS and non-PCOS categories using a fine-tuned MobileNet architecture. PCOS can affect women's reproductive health, and its assessment may involve multiple clinical and diagnostic factors. Therefore, the proposed system provides an automated approach that can support the analysis of ovarian ultrasound images.

In this study, transfer learning using MobileNet is applied to extract important features from the input images and perform classification. Image preprocessing and data augmentation are used to prepare the dataset and improve the ability of the model to generalize to different image variations. The model is trained using categorized ultrasound images, and its performance can be evaluated using measures such as accuracy, precision, recall, F1-score, and a confusion matrix.

The project's goal is to develop an automated and efficient approach for preliminary PCOS detection. Traditional analysis of ultrasound images requires medical knowledge and manual examination, whereas deep learning techniques can assist in identifying relevant image patterns automatically. The use of a lightweight MobileNet architecture reduces computational requirements and provides the possibility of deploying the proposed system in web-based or mobile-based healthcare support applications.

The system also incorporates Grad-CAM to provide an explanation for the classification results. The generated heatmaps highlight the regions of the ultrasound image that contribute to the model's prediction, thereby improving the transparency and interpretability of the system. The proposed approach demonstrates the potential of combining Deep Learning and Explainable Artificial Intelligence for medical image analysis. Furthermore, the system can be extended using larger datasets, additional clinical information, advanced deep learning architectures, and validation by medical professionals. The proposed system is intended to support preliminary screening and decision-making and should not replace professional medical diagnosis.

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