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Automated Detection of Diabetic Retinopathy and Associated Eye Conditions Using Fundus Images

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Abstract— One of the main complications of diabetes and the primary cause of blindness worldwide is diabetic retinopathy or DR. To prevent vision loss, early identification of diabetic retinopathy and related ocular diseases such cataracts, glaucoma, and macular edema is crucial. In this work, we describe an automated approach that uses fundus images to identify and classify DR and related ocular illnesses. We first extract features from fundus images using the VGG16 convolutional neural network (CNN) architecture, then for multi-class categorization, we employ an Extra Trees classifier. We established a remark- able 91.43% accuracy through experimental validation on a customized dataset from Kaggle, proving the efficacy of our method in detecting DR and related ocular disorders. Automated systems like ours hold great potential for enhancing healthcare outcomes by facilitating efficient screening and diagnosis of diabetic retinopathy and associated eye conditions.

Index Terms— VGG16, Extra trees classifier, cataract, macular edema, glaucoma, diabetic retinopathy, fundus images.

I. INTRODUCTION

Over the course of the past 10 years, Due to the substantial global risk of blindness associated with diabetic retinopathy (DR), early detection and treatment are crucial. Traditional methods of diagnosis, which rely on ophthalmologists doing manual examinations, are unreliable and time-consuming. To address these challenges, this study proposes an automated approach using fundus images, capturing detailed retinal views essential for diagnosing DR and associated conditions like macular edema, cataract, and glaucoma. Leveraging deep learning, specifically the VGG16 convolutional neural network (CNN) architecture, the method extracts meaningful features from fundus images. VGG16's proficiency in image feature extraction makes it well-suited for medical image analysis tasks. Additionally, the study employs the Extra Trees classifier, an ensemble learning technique, for multi-class classification. By combining VGG16 for feature extraction and Extra Trees for classification, the approach aims to enhance screening accuracy and reliability.

Experimental validation on publicly available datasets demonstrates the method's effectiveness in identifying DR and associated conditions accurately. This automated system holds promise for improving healthcare outcomes by facilitating early detection and intervention, ultimately reducing vision loss associated with diabetes. Automated screening programs empowered by deep learning techniques offer a transformative solution to the challenges posed by diabetic retinopathy, fostering timely interventions and mitigating the global burden of diabetic-related vision impairment. Fig 1 illustrates lesions of diabetic retinopathy.

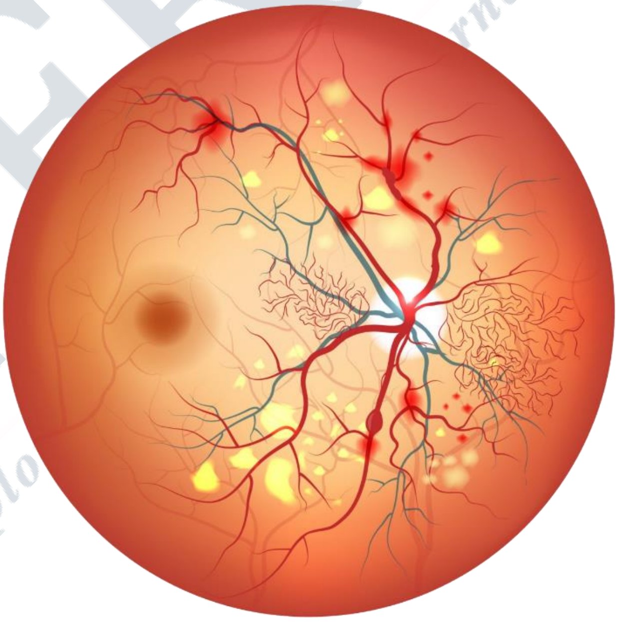

Fig 1. Illustrates diabetic retinopathy

II. RELATED WORKS

[1] Tahira Nazir et al. The suggested approach combines CenterNet for DME and DR detection with DenseNet-100 for feature extraction. It outperforms existing approaches with 97.93% accuracy on APTOS-2019 and 98.10% accuracy on IDRiD datasets. Its efficacy is confirmed by cross-validation using Diaretdb1 and EYEPACS, providing precise lesion detection under difficult circumstances. [2] Abdul Muiz Fayyaz et al. This study employs deep learning networks, AlexNet and ResNet101, for timely DR severity detection. Ant Colony system selects critical features, refined by Support Vector Machine, yielding a final classification model. With 93% accuracy on a dataset of DR fundus images,

it presents a potential automated solution for prompt treatment and vision preservation. [3] Masum Shah Junayed et al. In order to detect cataracts in fundus images, a unique deep neural network called CataractNet is proposed in this paper. Computational expenses can be decreased by optimizing the activation and loss functions and by using small kernels. CataractNet is an AI-based cataract detection tool that achieves 99.13% accuracy after being trained on 4746 enhanced photos. It suggests early intervention to prevent vision loss. [4] G. Kalyani et al. This paper presents a reformed capsule network for automated diabetic retinopathy detection and classification. Leveraging convolution and primary capsule layers, it achieves high ac- curacies on Messidor dataset: 97.98% for healthy retina, and 97.65% to 98.64% for different stages of retinopathy. This signifies significant progress in DR diagnosis using capsule networks. [5] Go¨zde Arslan et al. This study evaluates CNN architectures for eye disease detection using a dataset of 2748 Retinal Fundus images. EfficientNet emerges as the most effective, achieving 94.88% accuracy, recall, and precision, 95.02% F1-score, and 89.89% Matthews's coefficient correlation, showcasing deep learning's potential in accurate disease detection and classification.

[6] Ali Javed et al. An automated technique for the early detection of diabetic retinopathy, macular edema, and glaucoma is presented in this paper, which employs FRCNN and FKM clustering for disease localization and segmentation. It achieves 95% precision on datasets such as Diaretdb1, MESSIDOR, ORIGA, DR-HAGIS, and HRF, indicating its usefulness in disease diagnosis and classification in contrast to current approaches. [7] T Vijayan et al. This study uses a fine- tuned InceptionV3 CNN architecture with pre-trained weights to diagnose diabetic retinopathy (DR) through retinal fundus image processing. The method reduces training time and improves sensitivity and specificity, improving DR detection efficiency and potentially helping ophthalmologists by achieving 84.32% accuracy in binary class classification tests [8] M. Vamsi Krishna et al. In this work, a deep learning model for multi-class fundus image categorization of ophthalmological disorders called DeepID3 is introduced. Through thorough experimentation, the model achieves excellent performance with 99.23% accuracy by leveraging the flower pollination optimization approach and transfer learning from ImageNet for hyperparameter tuning. This shows greater performance compared to baseline methods. [9] Amin Valizadeh et al. This study proposes a CNN architecture for diabetic retinopathy detection using the IDRiD dataset. Achieving an 83.84% detection rate for target regions in fundus imagery from 80 patients, it presents a promising, cost-effective solution for assessing retinopathy severity without extensive manual examination by ophthalmologists. [10] Isaac Arias-Serrano et al. The study uses retinal fundus pictures to automatically detect diabetic retinopathy and glaucoma using an AlexNet CNN that has been retrained in MATLAB. The model obtains validation accuracy values for various datasets ranging from 89.7% to 94.3% through transfer learning.

III. METHODOLOGY

To predict Diabetic Retinopathy disorders, including Cataract, Glaucoma, Macular Edema, Diabetic Retinopathy, and Normal using retinal fundus images, we use machine learning and deep learning models; Fig. 2 illustrates our suggested approach.

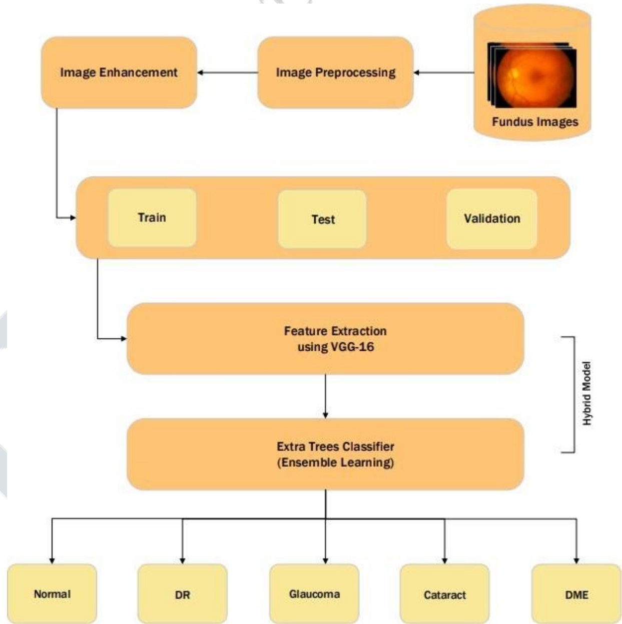

Fig 2. Proposed Methodology Diagram

A. Data Collection

Data collection is necessary in order to develop a strong algorithm that can identify eye issues from fundus photos. It is required to locate a variety of representative and diversified photographs that illustrate different eye conditions, such as glaucoma, cataracts, macular edema, and diabetic retinopathy. For this work, we used a customized dataset that we obtained from Kaggle. There were 5305 photos total, distributed over five categories of ocular diseases. All of the photographs in these classes had a resolution of 512*512 pixels, including 1074 images of normal healthy eyes, 1088 images of macular edema, 1098 images of diabetic retinopathy, 1007 images of glaucoma, and 1038 images of cataracts.

B. Image Preprocessing

Image preprocessing is crucial for effectively training and classifying fundus images. Techniques like normalization ensure pixel values are appropriately scaled for reliable training. Data augmentation, facilitated by the ImageDataGenerator class, improves dataset diversity and robustness. Scaling im- ages to a consistent size ensures conformity with model input requirements. These preprocessing steps collectively enhance model performance and generalization across diverse eye conditions.

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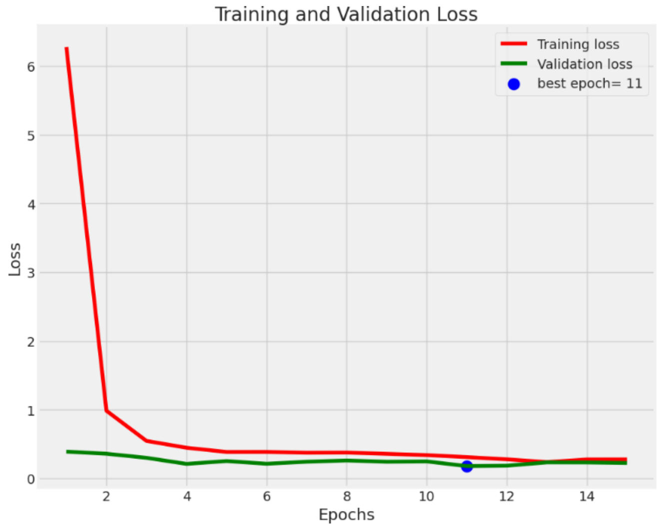

Fig 3. Training and validation loss of VGG16

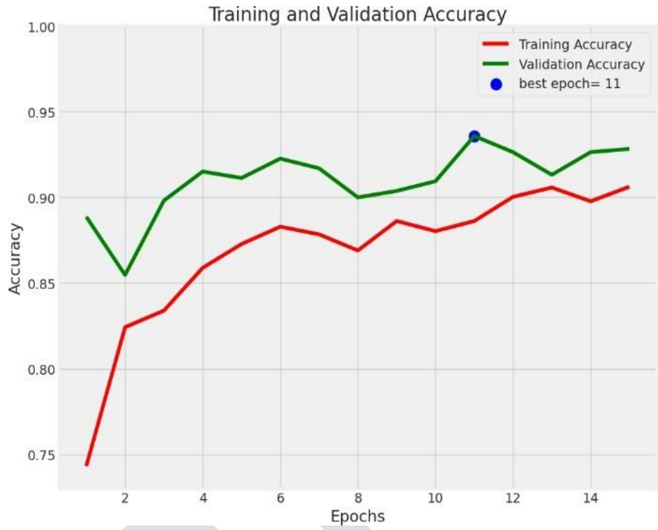

Fig 4. Training and validation accuracy of VGG16

C. Feature Extraction

Fundus picture analysis demands a critical step called feature extraction, where the trained VGG16 model from the ImageNet dataset acts as a potent feature extractor. By retaining the convolutional basis and removing fully connected layers, VGG16 effectively captures hierarchical features from fundus images, including patterns and structures crucial for distinguishing retinal diseases. The resulting feature maps represent high-level representations of input images, encoding details on forms, textures, and spatial arrangements of relevant structures like lesions and blood vessels. These feature maps are flattened into feature vectors and fed into a classification model, leveraging VGG16's capacity to identify fine-grained characteristics and patterns, thereby enhancing model performance without human feature engineering. Refer fig 3,4 for graphs.

D. Train, Test and Validation Set

To evaluate the model, the dataset was split into three categories: for training (80%), testing (10%), and validation (10%). While the testing set evaluated the model's performance on experimental data, the training set assisted with parameter learning. The validation set assisted in optimizing hyperparameters and preventing overfitting. Using new data, this method ensured an accurate evaluation of the model's classification performance for retinal images.

E. Classification using Extra Trees

The classification procedure involved extracting important features from fundus images using the trained VGG16 model's last convolutional layer. Leveraging VGG16's ability to capture complex structures and patterns, these features were crucial for precise categorization of diabetic retinopathy, macular edema, cataract, and glaucoma. Subsequently, an Extra Trees classifier, known for its ensemble learning approach and reduced risk of overfitting, was employed.

Through training, the classifier learned to associate target classes with input data features, enabling it to identify subtle variations and patterns for accurate predictions on new data. Performance evaluation using validation and test datasets assessed the classifier's accuracy, precision, recall, and F1-score, providing comprehensive insights into its ability to distinguish between different eye conditions. This rigorous evaluation aimed to determine the classifier's robustness and effectiveness in accurately classifying fundus images based on underlying pathology.

IV. EXPERIMENTAL ANALYSIS

The research shows the efficacy of a model that combines an Extra Tree classifier with the VGG16 architecture to diagnose diabetic retinopathy with an amazing 91.43% accuracy. Expert feature extraction of VGG16, which is essential for distinguishing minute details in fundus images, is the model's greatest strength. During training, convolutional layers were utilized to extract features. An input layer measuring 224 x 224 x 3 was used to input images, and a learning rate of 0.001 was used for a total of 15 epochs. The selection of hyperparameters during training increased the validation accuracy. The comprehensive evaluation through confusion matrix (Fig:5) values revealed the model's excellence across classes, achieving 91.43% accuracy, 91.78% precision, 91.34% recall, and a 91.31% F1-score. A detailed table (Fig: 6) elucidated the model's class-wise performance, encompassing specificity, sensitivity, recall, precision, F1 score, and accuracy metrics. The utilization of a small validation set efficiently determined class-wise performance for multiple eye disease categories, demonstrating the model's effectiveness. This remarkable accuracy positions the model as a promising diagnostic tool for early-stage diabetic retinopathy detection, with implications for enhanced patient outcomes and healthcare efficiency.

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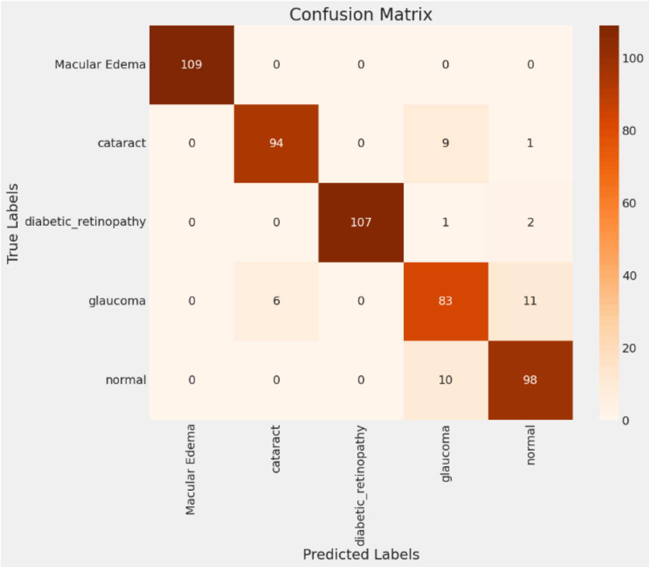

Fig 5. Confusion matrix

Class	Precision	Recall	F1-Score	Sensitivity	Specificity
Macular Edema	1	1	1	1	1
Cataract	0.84	0.89	0.87	0.89	0.97
Diabetic Retinopathy	1	1	1	1	1
Glaucoma	0.86	0.87	0.86	0.89	0.94
Normal	0.84	0.81	0.83	0.81	0.95

Fig 6. Performance of the suggested model per class

V. CONCLUSION

The work suggests a hybrid approach for the early identification of diabetic retinopathy (DR) from fundus pictures that makes use of transfer learning from the VGG-16 model. The Extra Trees classifier extracts features from DR pictures taken from a Kaggle dataset and achieves an astounding 91.43% average accuracy for multiclass classification. The hybrid model shows potential to support computer-aided healthcare systems by helping ophthalmologists identify and treat patients promptly. Future research efforts are expected to focus on growing and varying datasets in order to improve the resilience and effectiveness of machine learning algorithms in real- world scenarios. All things considered, the study significantly advances the creation of precise and useful diabetic retinopathy diagnostic methods.

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