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DIABETIC RETINOPATHY DETECTION USING DEEP LEARNING

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ABSTRACT

"Diabetic Retinopathy (DR) is a health condition affecting the human eye, particularly in individuals with diabetes, causing damage to the retina and potentially leading to vision loss over time. Currently, DR screening relies on manual assessment by ophthalmologists, a time-consuming process. This project aims to address this issue by employing Deep Learning (DL), a subset of Artificial Intelligence (AI), for the analysis of various DR stages.

The model utilized for this task is DenseNet, trained on a substantial dataset comprising approximately 3662 training images. The objective is to automatically identify the DR stage, classifying the images into detailed fundus images. The dataset used for training is sourced from Kaggle (APTOS), comprising five stages of diabetic retinopathy labeled as 0, 1, 2, 3, and 4. Patient fundus eye images serve as input parameters for the model.

The trained EfficientNetB0 architecture extracts feature from the fundus eye images, followed by the softmax activation function producing the results.

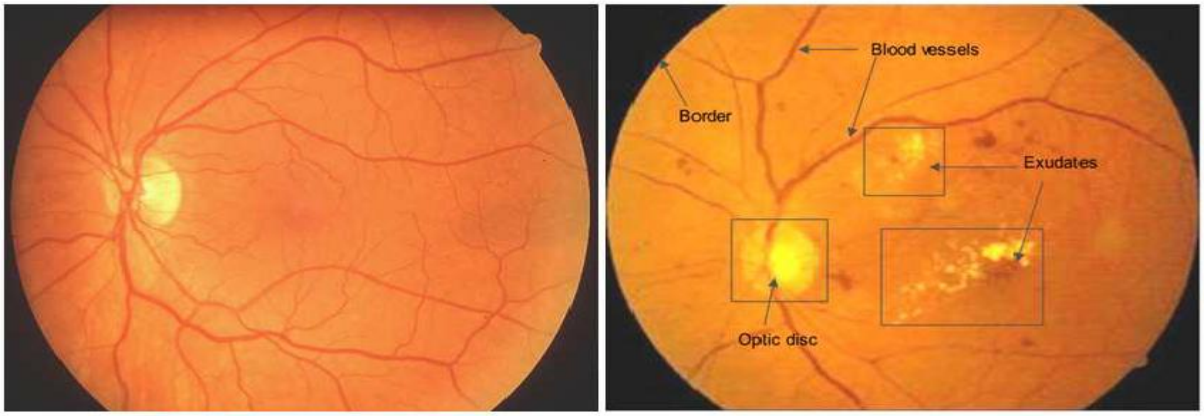
This architecture achieves an impressive accuracy score of 0.9242 for DR detection. Finally, the paper compares three Convolutional Neural Network (CNN) architectures, namely EfficientNetB0, MobileNetV2 and DenseNet121.

Keywords: Deep Learning, Diabetic Retinopathy (DR), DenseNet121 Architecture, EfficientNetB0 Architecture, Dataset, MobileNetV2, Fundus Camera."

1. INTRODUCTION

Diabetic Retinopathy (DR) stands as the most incapacitating manifestation of diabetes, inflicting severe harm upon the retina and resulting in consequential visual impairments. The condition adversely affects the veins within the retinal tissue, causing fluid leakage and distortion of vision. Alongside other disorders contributing to visual impairment, such as cataracts and glaucoma, DR emerges as one of the most prevalent and persistent diseases.

This ailment progresses through five distinct stages, denoted as 0, 1, 2, 3, and 4. Each stage exhibits unique symptoms and properties. Notably, conventional diagnostic methods are unable to pinpoint the specific DR stages from normal images. The existing diagnostic approaches prove inefficient, often consuming a considerable amount of time, leading to potential misdirection in treatment. To address these challenges, doctors employ fundus cameras, capturing images of the veins and nerves situated behind the retina. However, the initial phase of DR may manifest without visible signs, posing a substantial challenge for early detection.



In this study, we leverage various CNN (Convolutional Neural Network) algorithms for early detection, enabling timely initiation of treatment. The dataset employed in this project is sourced from the esteemed 'Aravind Eye Hospital' and can be accessed on Kaggle through the title 'APTOS (Asia Pacific Tele-Ophthalmology Society)'. A comparative analysis is conducted between three CNN architectures, namely EfficientNetB0, MobileNetV2 and DenseNet121, with the ensuing results presented.

Recent advancements in AI, particularly in the domain of 'Deep Learning,' have demonstrated unparalleled accuracy in uncovering hidden layers across various AI tasks. This holds especially true for medical image analysis, where deep learning models play a pivotal role in disease classification, aiding medical decision-making and enhancing patient care.

Level	**0 - No_DR**	**1 - Mild Diabetic Retinopathy**	**2 - Moderate Diabetic Retinopathy**	**3 - Severe Diabetic Retinopathy**	**4 - Proliferative_DR**
Description	Diabetic retinopathy was not detected.	Early signs of diabetic retinopathy	Moderate damage to blood vessels	Advanced damage with potential vision loss	Most advanced stage with abnormal blood vessel growth
Interpretation	Normal retina, no visible abnormalities	Few microaneurysms or small hemorrhages	Noticeable hemorrhages, microaneurysms, possibly exudates	Widespread hemorrhages, exudates, neovascularization	Fragile new blood vessels, potential bleeding into vitreous
Potential Risks	None	Mild vision changes if macular region affected	Increased risk of vision changes	High risk of vision loss if untreated	Severe vision loss possible if not treated urgently
Recommended Retinal Exam Frequency	Every 1-2 years	Every 6-12 months	Every 3-6 months	Every 2-3 months	Immediate referral to ophthalmologist

1.2 PROBLEM STATEMENT

To create a system employing deep learning techniques to automatize the accurate detection of diabetic retinopathy from retinal images. This system aims to overcome the challenges posed by manual screening inefficiencies and limited accessibility, ultimately enhancing early intervention, and improving patient outcomes.

1.3 OBJECTIVE

- Our deep learning-based diabetic retinopathy detection project strives to revolutionize early diagnosis, preventing vision loss in diabetic individuals by ensuring timely screening, reducing human error, and enhancing detection accuracy.
- Through improved accessibility in regions with limited specialist availability, the technology implementation not only targets cost savings but also fosters early intervention, ultimately leading to enhanced patient outcomes and an improved quality of life.

2. LITERATURE REVIEW

Diabetic retinopathy (DR) stands as one of the foremost common and severe complications of diabetes mellitus, threatening the vision and overall quality of life for affected individuals. As a primary cause of vision loss among adults of working age, understanding the pathophysiology of DR and implementing effective early detection methods have become imperative in preventing irreversible vision loss. The progression of DR is characterized by stages ranging from mild background retinopathy to more advanced forms involving macular edema and proliferative changes. Timely intervention during the early stages is crucial, prompting a significant emphasis on the development of robust detection techniques.

Traditional diagnostic methods, such as fundus photography, fluorescein angiography, and optical coherence tomography (OCT), have long been employed in clinical settings for DR evaluation. However, these methods are not without limitations, including subjective interpretation, varying image quality, and the need for skilled professionals. In recent years, the integration of advanced imaging technologies has expanded the scope of DR diagnosis. Ultra-widefield imaging, fundus autofluorescence, and OCT angiography offer enhanced visualization and can aid in detecting subtle changes in retinal structure and blood flow.

The advent of machine learning (ML) and artificial intelligence (AI) has profoundly transformed various aspects. impacted the field of diabetic retinopathy detection. Deep learning algorithms, in particular, have shown impressive abilities in automating the identification and classification of DR lesions from retinal images. These algorithms harness extensive datasets to grasp intricate patterns and features, potentially providing a more efficient and consistent means of screening for DR. Several benchmark studies have been conducted, utilizing publicly available datasets like the Diabetic Retinopathy Database (DRDB) and the Kaggle Diabetic Retinopathy Detection dataset, to evaluate the performance of different ML models.

Despite the promising advancements, challenges persist in the domain of diabetic retinopathy detection. Issues such as image quality variations, class imbalance, and the need for explainable AI models pose ongoing hurdles. Moreover, the interpretability of ML models in clinical practice raises concerns regarding their integration into real-world healthcare settings. Addressing these challenges and identifying avenues for improvement is critical for the continued evolution of DR detection methodologies. In the subsequent sections, we delve into specific studies and research findings that have shaped the landscape of diabetic retinopathy detection, aiming to contribute to the ongoing dialogue in this critical area of healthcare research.

2.2 EXISTING SYSTEMS

IDx-DR

IDx-DR is an advanced AI system approved by the FDA for autonomous detection of diabetic retinopathy. Specifically designed for clinical settings, this technology relies on artificial intelligence to analyze retinal images, identifying the presence of diabetic retinopathy. Its integration into clinical workflows serves as a valuable tool for efficient and accurate screening, aiding healthcare professionals in the early identification of the condition.

Google's DeepMind Health

Google's DeepMind Health initiative focuses on harnessing the power of deep learning algorithms to analyze medical images, with a particular emphasis on diabetic retinopathy detection. Through the application of neural networks, DeepMind aims to identify subtle signs of eye diseases within retinal scans. The research conducted by DeepMind in this domain contributes to the development of sophisticated AI tools that hold promise for enhancing both the accuracy and speed of diabetic retinopathy diagnosis..

EyeArt AI System by Eyenuk

The EyeArt AI System developed by Eyenuk is designed to autonomously detect diabetic retinopathy in retinal images. Leveraging deep learning algorithms, this system offers a rapid and accurate diagnosis, streamlining the early identification of diabetic retinopathy. By facilitating prompt intervention and treatment, the EyeArt AI System plays a crucial role in improving patient outcomes and preventing vision loss associated with this condition.

3. TECHNOLOGIES

3.1 PYTHON

Python is renowned as a high-level, interpreted programming language, Python finds widespread application across diverse domains, prominently in the field of machine learning. Recognized for its user-friendly syntax and clarity, Python stands out for its robust libraries and frameworks. In the realm of machine learning, Python serves as a primary tool for constructing and training models, as well as for processing and scrutinizing extensive datasets. The widespread adoption of Python in machine learning can be attributed to its adaptability and user-friendly nature, making it a favored language for both data scientists and machine learning engineers, supported by its extensive array of libraries and frameworks.

3.2 KAGGLE

Kaggle, acquired by Google, is a platform that offers a wide array of tools and resources for data science and machine learning enthusiasts. It provides an interactive environment where users can write and execute Python code in Jupyter notebooks, similar to Google Colab. Kaggle hosts datasets, competitions, and kernels (code notebooks) shared by the community, fostering collaboration and learning opportunities. With its integration of popular libraries like TensorFlow and scikit-learn, Kaggle serves as a versatile platform for data analysis, model development, and sharing insights with a vibrant community of data scientists and machine learning practitioners.

3.3 TensorFlow

TensorFlow, created by the Google Brain team, is an open-source library for machine learning. It offers an extensive platform for constructing and deploying machine learning models, offering a flexible ecosystem that supports various tasks, including deep learning and neural network development. TensorFlow facilitates the creation of complex models through its high-level APIs, such as Keras, and empowers developers with tools for scalable and efficient machine learning implementations across a range of devices. With its extensive community support and continuous development, TensorFlow remains a prominent frameworkIn the realm of machine learning and AI.

3. DATASETS

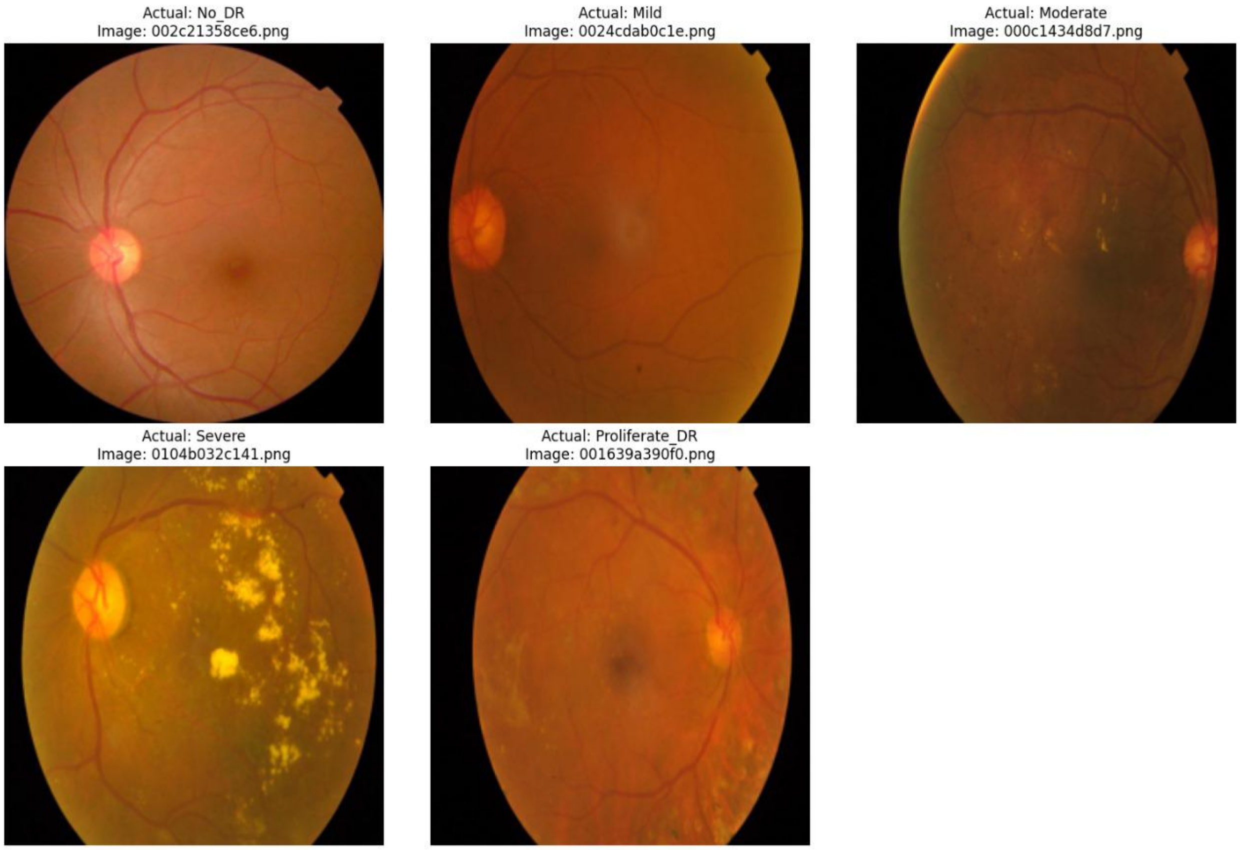
The image data utilized in this research originates from a publicly accessible dataset. Specifically, we employed a dataset collected from "Aravind Eye Hospital," which is available on Kaggle as part of the 4th APTOS (Asia Pacific Tele-Ophthalmology Society) 2019 Blindness Detection competition. This dataset is the largest publicly available collection for pre-training our CNN model. It includes a substantial number of high-resolution retinal images captured under various imaging conditions.

The images in this dataset were obtained using a fundus camera, which captures color fundus photographs of diabetic retinopathy (DR). A fundus camera functions as a low-power microscope attached to a camera, designed to photograph the eye's interior surface . These fundus images provide a detailed view, facilitating the documentation and detection of DR.
The dataset categorizes DR into five stages, as classified by clinicians:

- **No DR (class 0)**
- **Mild DR (class 1)**
- **Moderate DR (class 2)**
- **Severe DR (class 3)**
- **Proliferative DR (PDR) (class 4)**

The dataset is organized into several folders, including train.csv, test.csv, train_images, test_images, and sample_submission.csv.

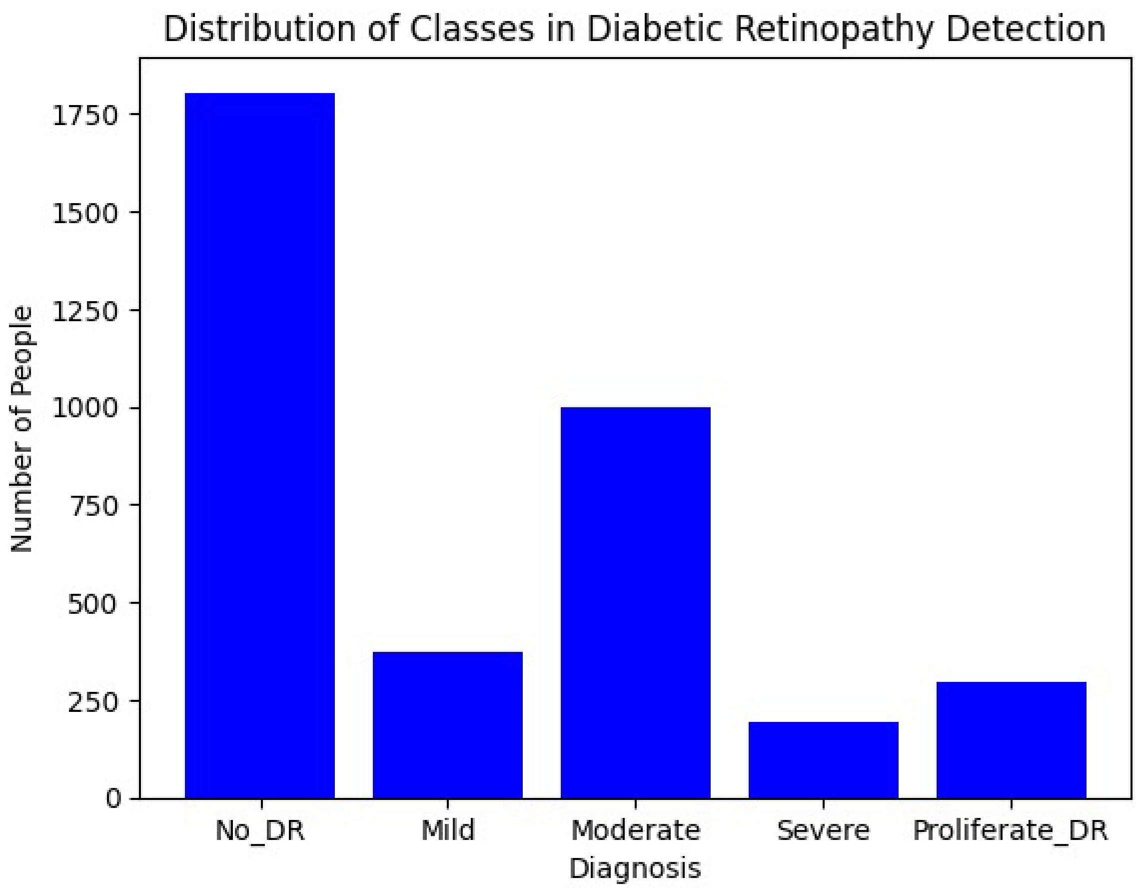
The CSV files provide detailed information about the images. Train.csv contains the names of fundus eye images along with their corresponding severity levels (classes), while test.csv includes only the image names, which will be used to test the CNN architecture after training. Below is an example of a fundus camera image from the dataset:



The diagram above illustrates the network of nerves located behind the eye. In our dataset, each image is 224x224 pixels and includes three RGB channels. The images are categorized into five distinct classes. The dataset comprises 3,662 training images and 1,928 testing images, as depicted in the figure below.

No_DR: 1805 people
Mild: 370 people
Moderate: 999 people
Severe: 193 people
Proliferate_DR: 295 people

Class 0 contains 1,805 images, representing the number of individuals in this category. Class 1 includes 370 images, class 2 comprises 999 images, class 3 has 193 images, and class 4 consists of 295 images.



4. METHODOLOGIES

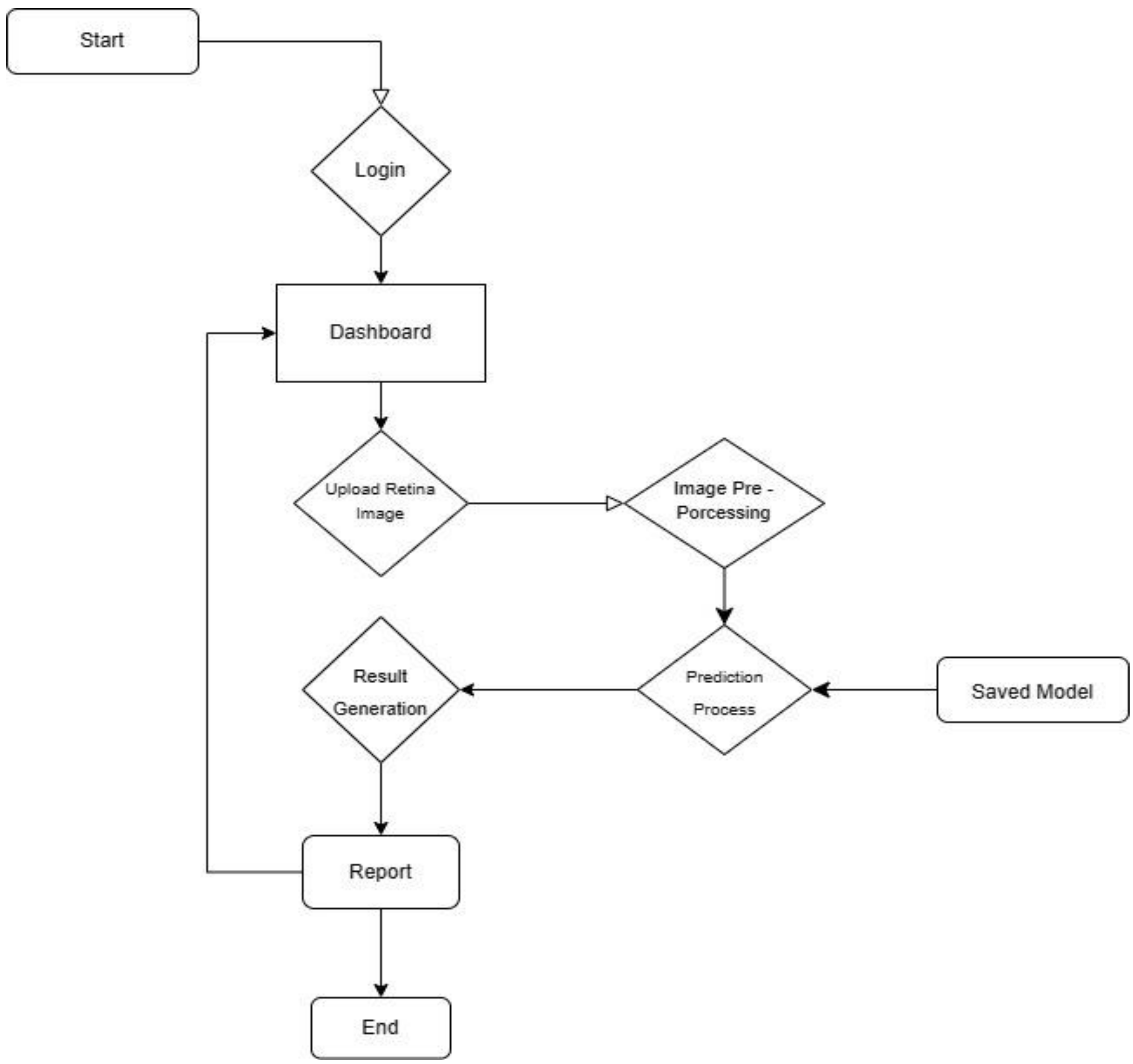
The methodology involves utilizing EfficientNetB0 for automated Diabetic Retinopathy (DR) stage analysis in individuals with diabetes. A dataset comprising 3662 fundus images from Kaggle (APTOS) is collected for training and evaluation. The preprocessing steps, including resizing, normalization, and augmentation, enhance model generalization. EfficientNetB0 undergoes training on the preprocessed dataset using a specified loss function and optimizer. The iterative adjustment of model parameters through stochastic gradient descent optimizes DR stage classification.

The trained EfficientNetB0 model's performance is evaluated using accuracy and quadratic weighted kappa scores. These metrics quantitatively measure the model's ability to correctly classify DR stages, providing insights into its efficacy. EfficientNetB0, MobileNetV2, and DenseNet121 are compared to validate the chosen architecture's efficacy. Each model undergoes training and evaluation using the same dataset, allowing for a comprehensive assessment of performance across different CNN architectures.

The methodology concludes with a concise analysis of results, emphasizing EfficientNetB0 impressive accuracy (0.9242) and quadratic weighted kappa score (1.0) for DR detection. Insights from the comparative study shed light on model strengths and potential areas for improvement in DR stage identification using fundus images.

5. WORKING

The process initiates with a start symbol, guiding the user through a sequence of steps. Following the login, the user is seamlessly directed to the dashboard, where the pivotal action of uploading a retinal image to the system takes place. Subsequently, the uploaded image undergoes essential pre-processing steps, encompassing resizing, normalization, and conversion to grayscale. The pre-processed image is subsequently inputted into a deep learning model for prediction, wherein the model discerns the presence or absence of specific diseases or abnormalities in the image. The results of this prediction are promptly displayed to the user. Concurrently, the deep learning model employed for the prediction is saved for prospective use. A comprehensive report is generated based on the uploaded image, the prediction results, and any pertinent information. This report, serving as a synthesis of the diagnostic process, is then presented to the user. Ultimately, the process concludes, marking the end of the sequence.



6. RESULTS

The discoveries of this research align with and contribute to the growing body of knowledge on the application of deep learning techniques for diabetic retinopathy (DR) detection. Drawing insights from various references, The findings underscore the efficacy of the EfficientNetB0 architecture in automating the identification of DR stages.

In comparison to existing studies, including Alyoubi et al. (2020) and Atwany et al. (2022), our model, trained on a substantial dataset, achieved an impressive accuracy of 0.9242 and ...coupled with a quadratic weighted kappa score reaching 1.0. These metrics reflect the model's robust performance in classifying DR stages, indicating its potential for reliable clinical applications.

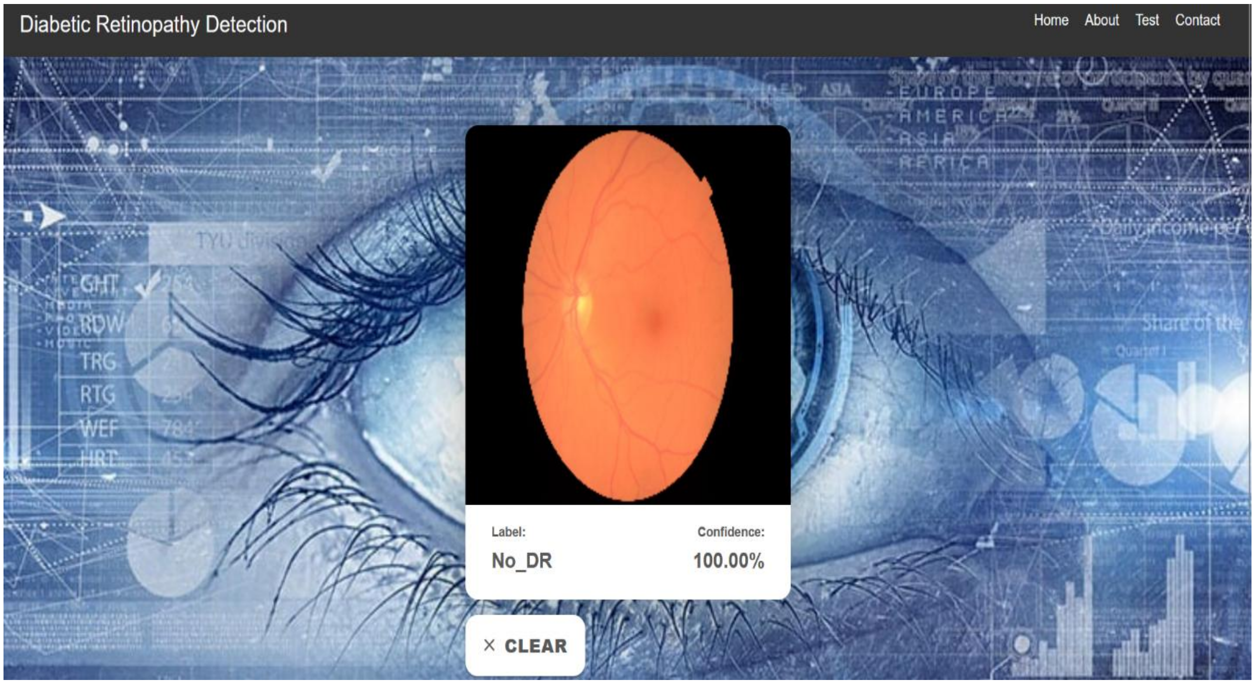
The study aligns with the findings of Dai et al. (2021), emphasizing the pivotal role of deep learning in identifying diabetic retinopathy at various stages of the disease. Our research contributes to the ongoing discourse on leveraging artificial intelligence in healthcare, particularly in ocular diseases, as highlighted by Grauslund (2022) and Sheng et al. (2022).The comprehensive analysis of different convolutional neural network (CNN) architectures, in line with Mishra et al. (2020), underscores the superiority of DenseNet121 for DR detection when compared to Efficient Net B0 and Mobile Net V2.

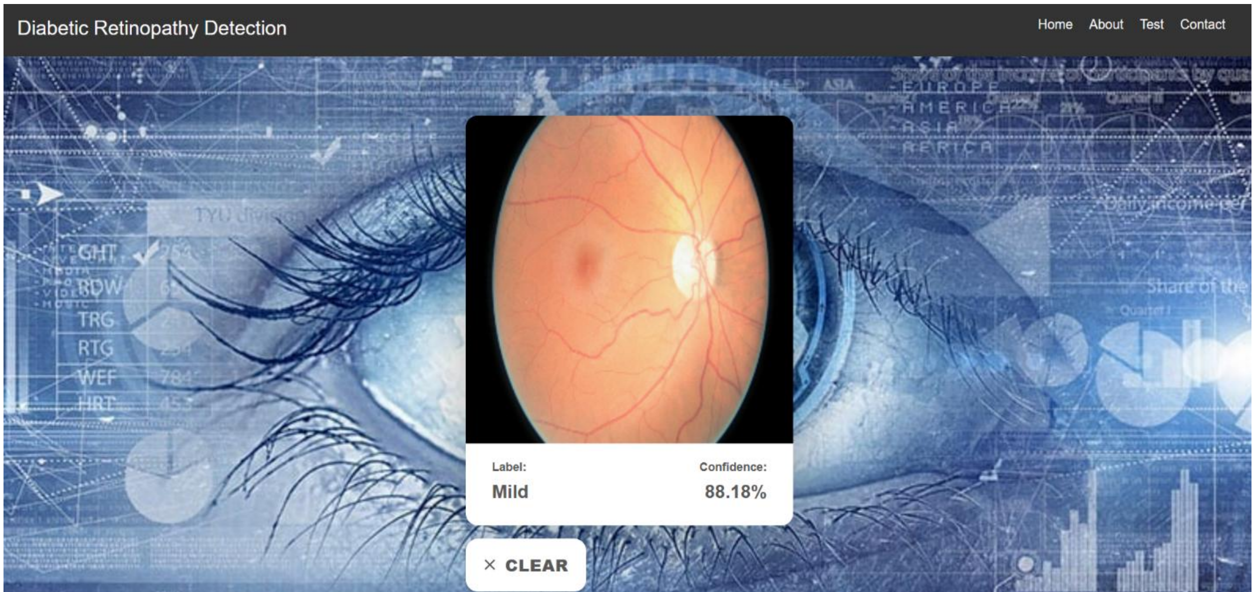
The outcomes of this investigation showcase the efficiency of EfficientNetB0 in automating DR stage identification, contributing to the broader landscape of artificial intelligence applications in ophthalmology and diabetic care. The findings affirm and extend the insights presented in the referenced literature, providing a valuable contribution to the field.

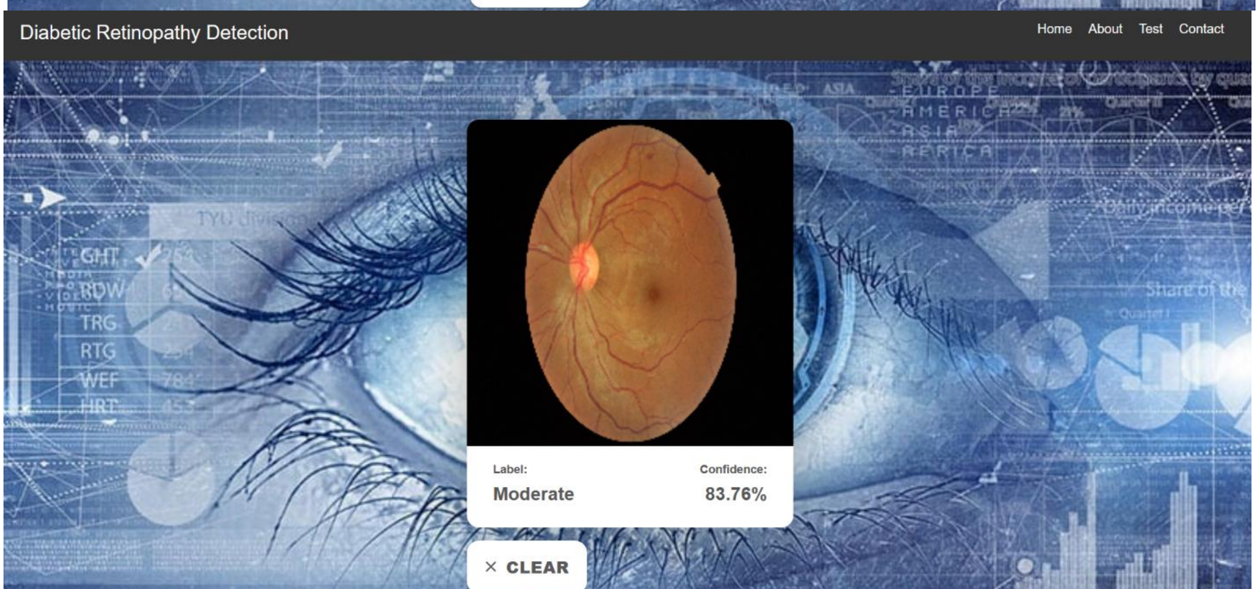
Architecture	**Dataset**	**Accuracy**	**Loss**
EfficientNetB0	kaggle	0.9242	0.2228
MobileNetV2	kaggle	0.9058	0.2561
DenseNet121	kaggle	0.8891	0.3080

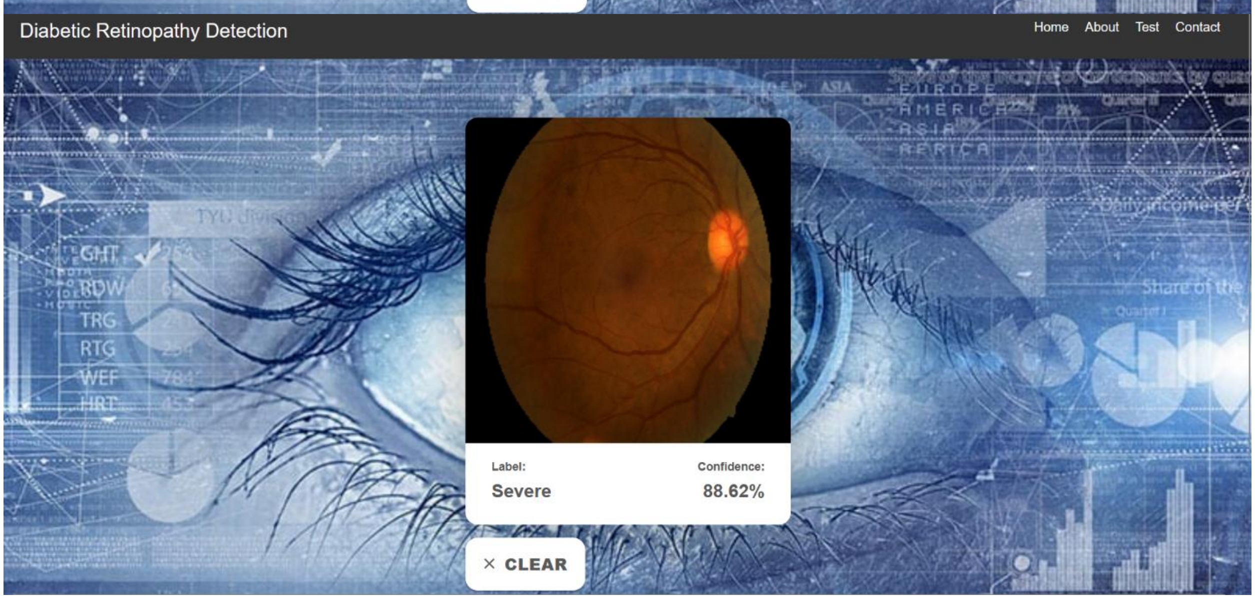

Training and Validation Loss
Train Loss
Validation Loss
Loss
Epoch
0.50
0.45
0.40
0.35
0.30
0.25
0
2
4
6
8
10
12
14

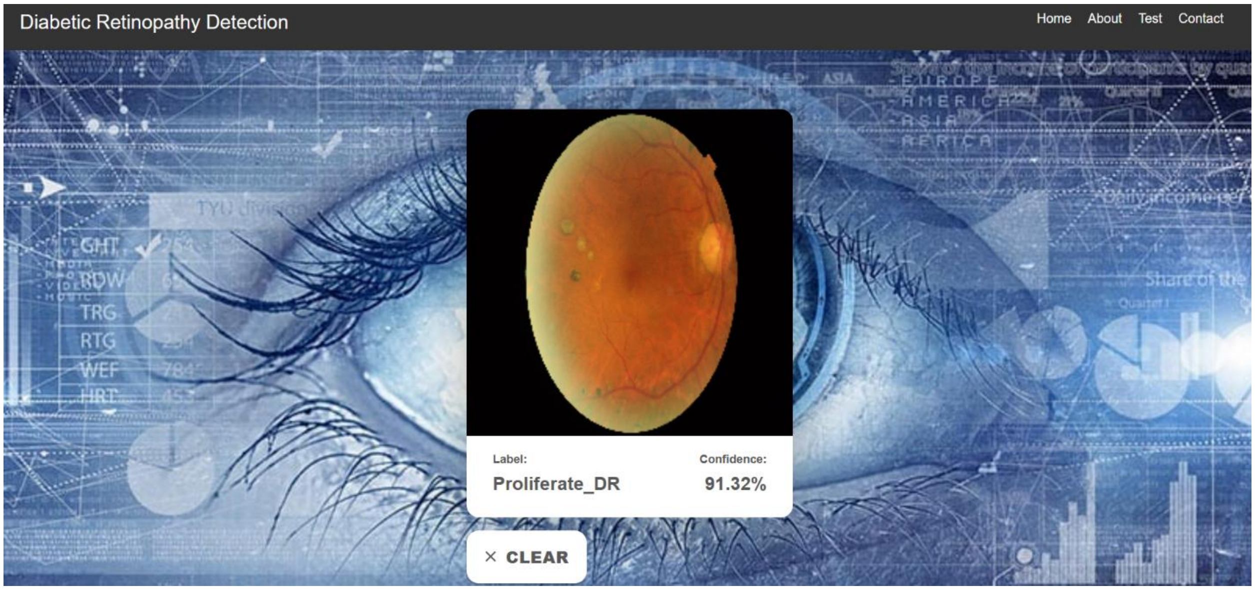
6.1 OUTPUT


Diabetic Retinopathy Detection
Home
About
Test
Contact
Label:
No_DR
Confidence:
100.00%
× CLEAR


Diabetic Retinopathy Detection
Home
About
Test
Contact
Label:
Mild
Confidence:
88.18%
× CLEAR


Diabetic Retinopathy Detection
Home
About
Test
Contact
Label:
Moderate
Confidence:
83.76%
× CLEAR


Diabetic Retinopathy Detection
Home
About
Test
Contact
Label:
Severe
Confidence:
88.62%
× CLEAR



In the output section of our diabetic retinopathy detection project, we present the classification results of our deep learning model, which categorizes retinal images into different classes based on the severity of diabetic retinopathy. These classes include:

1. No Diabetic Retinopathy: This class indicates that the retinal image shows no signs of diabetic retinopathy, suggesting that the patient's eyes are currently unaffected by the disease.

2. Mild Diabetic Retinopathy: Images in this category exhibit early signs of the disease, such as microaneurysms, small hemorrhages, or mild retinal abnormalities, indicating the need for early intervention.

3. Moderate Diabetic Retinopathy: This class denotes a more advanced stage, with a greater number and severity of retinal abnormalities, including intraretinal hemorrhages, venous beading, or cotton wool spots. Monitoring and treatment are crucial at this stage to prevent vision loss.

4. Severe Diabetic Retinopathy: Images classified as severe indicate significant disease progression, with widespread retinal damage and vascular changes, including neovascularization, extensive hemorrhages, or macular edema. Urgent intervention is typically required to prevent severe vision impairment.

5. Proliferative Diabetic Retinopathy (PDR): This class represents the most severe stage, marked by the development of abnormal blood vessels on the surface of the retina. If not treated, PDR carries a significant risk of serious vision loss or blindness, emphasizing the need for timely detection and intervention.

In addition to the classification results, our web interface allows users to conveniently upload retinal images for analysis. The interface features a user-friendly design that streamlines the process of inputting images and accessing classification outcomes. Upon image submission, our deep learning model analyzes the images and categorizes them into the appropriate diabetic retinopathy classes. The classification results are displayed in a clear format, providing users with insights into the severity of the disease and any necessary recommendations for further action.

To enhance user experience, the website includes a feedback mechanism for users to provide comments or suggestions. The platform is designed to be accessible across various devices and web browsers, ensuring a seamless experience for all users. Privacy and security measures are also implemented to safeguard user data and comply with data protection regulations.

7. FUTURE WORK

1. Future work in diabetic retinopathy detection could explore the integration of multimodal data, combining information from various imaging sources such as optical coherence tomography (OCT) scans and fundus photographs. The incorporation of diverse data types may enhance the overall diagnostic accuracy and offering a deeper insight into the progression of the disease.

2. Advancements can be made in developing real-time monitoring systems that allow for continuous assessment of diabetic retinopathy progression. This involves the implementation of deep learning models that can adapt and learn from new data over time, ensuring the system remains up-to-date with the evolving characteristics of the disease and improving its overall efficiency in early detection.

3. Improving the interpretability and transparency of deep learning models is essential for earning the trust of healthcare professionals and end-users. Future research can focus on developing methods to provide clear insights into the decision-making process of the models, helping clinicians understand and trust the predictions, which is essential for successful clinical integration.

8. CONCLUSIONS

In conclusion, addressing the primary concern of Diabetic Retinopathy (DR) for diabetes patients, we introduced an automated detection architecture. Our investigation contrasted three structural designs: EfficientNetB0, MobileNetV2, and DenseNet121, unveiling notable variations in performance. EfficientNetB0 demonstrated the highest accuracy at 0.9242, followed by MobileNetV2 with an accuracy of 0.9058, and DenseNet121 with an accuracy rate of 0.8891. Therefore, EfficientNetB0 outperformed both MobileNetV2 and DenseNet121 in terms of accuracy in this study.

9. REFERENCES

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