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Diabetic Retinopathy Detection

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Abstract: Diabetic retinopathy (DR) is one of the most serious complications of diabetes, which affects the retina and can lead to impaired vision or blindness if detected and treated late. The project develops an A.I. based diagnostic system whose SDL with classified grading for DR identification using retinal fundus images. The system uses CNNs-based medical image analysis and divides it into five different classes: No_DR, Mild, Moderate, Severe, and Proliferative_DR. Image preprocessing enhances the extraction of features and prediction accuracy. To further improve accessibility, the project includes a web application based on Flask which allows users to upload their images and instantly receive a diagnostic report. The development also reduces medical professionals' workload while providing a scalable way to massively address the rising tide of diabetes-related blindness, thus making quality eye care available everywhere.

Keywords: Diabetic Retinopathy (DR), Medical Image Analysis, Convolutional Neural Networks (CNNs), Retinal Fundus Images, Automated Diagnosis, Web Application.

Research Paper

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I. INTRODUCTION

Increased prevalence of diabetes worldwide has brought about a steep rise in the number of cases of diabetic retinopathy, which is still one of the most important causes of blindness in adults. Diagnosis requires specialized expertise and equipment, which are often non-existent in under-resourced regions. Manual assessment of fundus photographs possesses an inherent labor intensive and subjective nature, leading to a number of inconsistencies. Moreover, the delayed diagnosis of DR stages means interruption in potential interventions, causing higher disease progression rates. Current automated methods, however promising, are frequently not scalable, affordable, or generalizable across diverse populations. This project describes the impending problem as urgent: an accessible, accurate, and quick automated system for the diagnosis and classification of the severity of DR, addressing clinical and infrastructure- related concerns.

The diabetic retinopathy detection project aims to tackle the increasing demand for healthcare's automated diagnostic tools, especially for diabetic retinopathy (DR), a major cause of blindness around the world. With deep learning advances, it exploits leading-edge techniques to deliver an accurate, scalable, and accessible solution for the identification and classification of DR stages. By combining robust AI models with user-friendly interfaces, it aims to increase healthcare efficiency, accuracy, and accessibility.

This paper is divided into seven sections. Section II discusses background of diabetic retinopathy disease and works undertaken to improve healthcare accessibility using advanced technologies. Section III outlines the proposed system's architecture and functionalities, focusing on modules such as User Interface Module, Image Processing Module, Feature Extraction Module, Database and Web Application Module. Section IV presents the analysed results, including system performance and user experience evaluations. The findings are summarized in Section V, along with the project's conclusion and future scope for enhancements. Finally the Section VI contains the references used while building this project.

II. BACKGROUND

Diabetic retinopathy (also known as diabetic eye disease) is a medical condition in which damage occurs to the retina due to diabetes. It is a leading cause of blindness in developed countries and one of the lead causes of sight loss in the world, even though there are many new therapies and improved treatments for helping people live with diabetes.

In 1851, the invention of the direct ophthalmoscope opened the door for in vivo fundoscopy. As a result of this invention, ocular manifestations of systemic diseases could be identified and classified for the first time. Five years after the invention of the direct ophthalmoscope, Austrian physician Eduard Jäger described the increased incidence of retinal exudates in diabetic eyes. In his paper entitled “Beiträge zum Pathologie des Auges”, he included twenty fundus drawings, and made the first claims that there was a direct correlation. In dispute with Jäger’s observation, German physician Albrecht von Graefe argued that Jäger could not prove causality between diabetes and retinal vascular complications such as retinal exudates. Unfortunately, the belief that diabetes caused vascular changes in the retina remained controversial for the next two decades due to a lack of histopathologic proof; however, by 1872, British ophthalmologist Edward Nettleship confirmed Jäger’s theory in his landmark paper entitled, “on oedema or cystic disease of the retina”. This paper provided the first histopathological proof of cystoid macular changes in patients with diabetes.

This was followed by multiple other ophthalmologists, such as Wilhelm Manz, who wrote about his observations of ocular manifestations of diabetes such as tractional retinal detachments and vitreous hemorrhages in his paper entitled “retinitis proliferans”. Despite Jäger’s and Nettleship’s publications, the debate persisted into the early 20th century as to whether the macular findings were directly related to diabetes, or whether they were due to other vasculopathic risk factors that are commonly found in diabetics, such as atherosclerosis. In 1944, ophthalmologists Ballantyne and Lowenstein first used the term “diabetic retinopathy”, and Scottish physician Arthur James Ballantyne also provided further evidence that diabetic retinopathy was a unique vasculopathy.

By 1985, the Early Treatment Diabetic Retinopathy Study (ETDRS) would publish the data from its five year trial and would further standardize management strategies for diabetic retinopathy. Its goal was to evaluate the effectiveness of both argon LASER photocoagulation and aspirin therapy in delaying or preventing progression of the disease. Aspirin was found to have zero effect on the progression of retinopathy, but did reduce cardiovascular risk and did not increase the risk for vitreous hemorrhage. The study standardized the definition of “clinically significant macular edema (CSME)”, and demonstrated a clear benefit of focal macular LASER.

Modern day treatment of diabetic macular edema relies more heavily on the results of macular optical coherence tomography (OCT) than it does fluorescein angiography. The first in vivo OCT images of the retina were published in 1993, and gained widespread clinical use by the late 1990’s. Optical coherence tomography is a light-based technique that provides tissue imagery at high resolutions and can yield great accuracy in the diagnosis of diabetic macular edema. It is a non-invasive imaging modality that is routinely performed to monitor DME progression at the molecular level and can help determine whether or not to initiate treatment for diabetic macular edema.

While diabetes has many ocular complications, recent years have brought many advancements in the areas of treatments and imaging modalities. Traditional methods for diagnosing diabetic retinopathy rely on manual examination of fundus images by ophthalmologists using ophthalmoscopes or fundus cameras. While effective, these approaches are often subject to variability due to individual expertise and fatigue. Automated systems, such as Google's AI-based DR detection platform, utilize machine learning algorithms for retinal image classification, and some clinical tools incorporate Optical Coherence Tomography (OCT) for detailed retina analysis. However, these methods face several limitations. Manual diagnosis is inherently subjective and prone to inconsistencies. Accessibility barriers arise due to the high costs and specific equipment requirements, making these solutions unsuitable for rural or under-resourced regions. Traditional methods are also time-consuming, hindering their utility in mass screenings. Furthermore, existing AI-based systems often struggle with data generalization due to a lack of diverse training datasets, and proprietary solutions are computationally intensive, posing scalability challenges for widespread deployment.

III. METHODOLOGY

The proposed system addresses the limitations of existing solutions by offering an automated, accurate, and accessible diagnostic tool for diabetic retinopathy detection.

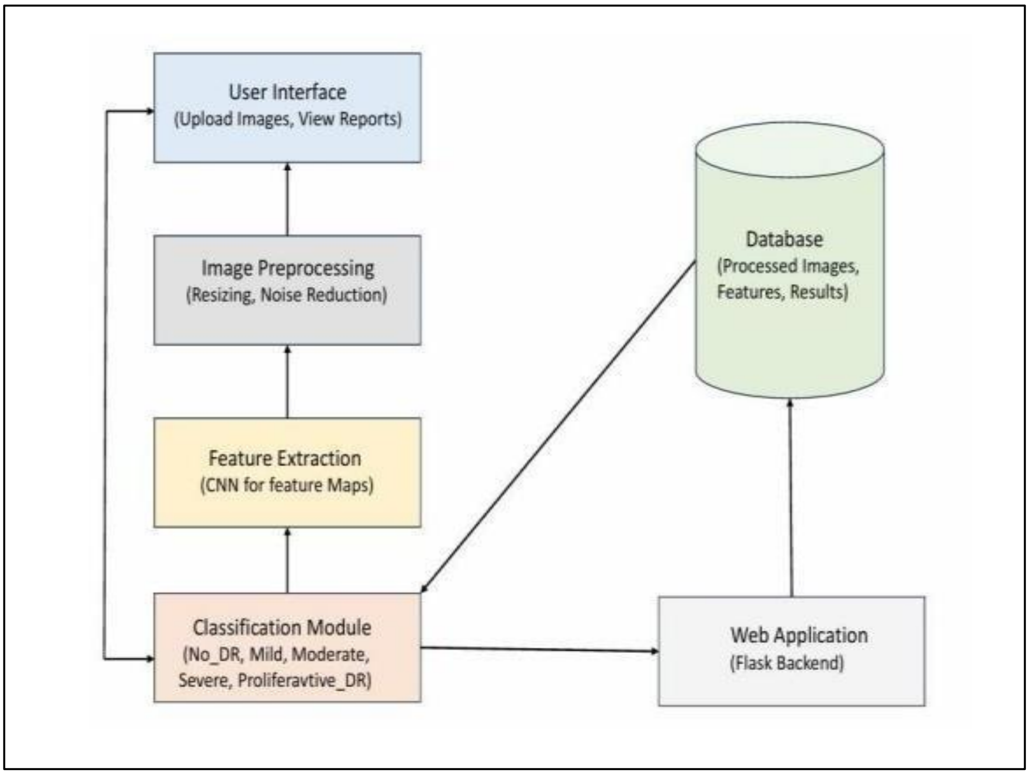

Fig. 1: System Architecture

A. *User Interface*

The system features a Flask-based user-friendly interface, allowing non-technical users to easily upload retinal images and view diagnostic results without requiring specialized knowledge. Users receive instantaneous predictions and statistical summaries, enabling timely decision-making and enhancing the system's usability in clinical settings.

It includes a login page for authentication, a welcome page with navigation options, and a home page for uploading images with file input, drag-and- drop, and previews. A processing page displays a loading animation, while output pages show predictions, explanations, and actionable links. The about page provides an overview of diabetic retinopathy, and the contact page allows user inquiries. A statistics page can include a pie chart summarizing predictions and a downloadable CSV of past results.

B. *Image Processing*

Image Processing prepares uploaded images by enhancing quality and standardizing dimensions which ensures accurate predictions. Uploaded images are first converted to RGB and then to YCrCb format for enhanced contrast using CLAHE (Contrast Limited Adaptive Histogram Equalization). The processed image's brightness channel is adjusted, and the modified YCrCb image is converted back to RGB.

Further preprocessing involves Gaussian Blur to reduce noise and resizing the image to a target size (e.g., 224x224) suitable for the model. During prediction, the processed image is normalized using the training data's mean and standard deviation via an ImageDataGenerator to match the model's input requirements.

C. *Feature Extraction*

Feature extraction is performed implicitly by the deep learning model. The model, based on a convolutional neural network (CNN), automatically extracts relevant features such as blood vessel patterns, microaneurysms, hemorrhages, and other retinal abnormalities from preprocessed images. Convolutional layers identify low-level features (e.g., edges, textures) in the initial layers and progressively detect high-level, disease-specific patterns in deeper layers. These extracted features are then passed through fully connected layers to predict the severity of diabetic retinopathy. This automated feature extraction, combined with preprocessing pipeline (CLAHE, Gaussian Blur, and normalization), ensures that the model focuses on critical visual cues for accurate classification.

D. *Image Classification*

Image classification is performed using a deep learning model. After preprocessing, the input images are fed into the model, which uses a series of convolutional, pooling, and fully connected layers to classify them into one of five categories: Mild, Moderate, No_DR, Proliferate_DR, and Severe. The model outputs probabilities for each class, and the class with the highest probability is selected as the prediction. This classification process leverages features such as microaneurysms, hemorrhages, and abnormal blood vessel patterns extracted during earlier layers. The model is a CNN-based model trained on a labeled retinal image dataset, categorizes images, ensures robust classification performance by learning complex visual patterns specific to diabetic retinopathy.

E. Database

The database is a critical component for organizing and managing the training and prediction data. It consists of a collection of labeled retinal images, arranged in a directory structure with subfolders corresponding to each class of diabetic retinopathy (e.g., Mild, Moderate, No_DR, Proliferate_DR, and Severe). These images are sourced from the training dataset, where each subfolder holds images categorized by the severity of diabetic retinopathy, facilitating structured data access. During training, images are preprocessed using techniques like CLAHE (Contrast Limited Adaptive Histogram Equalization) for contrast enhancement, Gaussian blur to reduce noise, and resizing to standard dimensions, ensuring consistency before feeding the images into the deep learning model.

Once the model makes predictions, the outcomes are stored in a CSV file, which logs key information such as the image name and its corresponding predicted class. This CSV serves as a valuable repository for tracking predictions, storing metadata, and analyzing the model's performance over time. The organization of images within the database allows for easy management and retrieval, ensuring that data is structured in a way that supports efficient model training and subsequent analysis of prediction trends and accuracy. This approach not only aids in monitoring the model's performance but also ensures the database is scalable and manageable for future updates or data expansions.

F. Web Application

Web application is built using Flask, a lightweight Python framework, to provide an interactive interface for diabetic retinopathy detection. It allows users to upload retinal images for processing and receive predictions based on the trained model. The app's core features include user authentication (via a login page), image upload functionality (with drag-and-drop and file input support), and displaying predictions on dedicated output pages. The app processes the uploaded images, applies necessary preprocessing steps, and uses a pre-trained deep learning model to classify the images into one of five diabetic retinopathy stages. The results are shown in real-time, with a user-friendly UI for interaction. The app also includes pages for statistics (displaying prediction summaries) and contact and about sections for user support and information. Flask's routing system is used to handle navigation between these pages, while HTML templates manage the UI, and static files (CSS, JS, images) enhance the user experience.

IV. RESULTS AND DISCUSSIONS

The result of the diabetic retinopathy detection process is a crucial aspect, as it provides users with the classification outcome based on the analysis of uploaded retinal images.

The model accurately classifies images into one of the five diabetic retinopathy stages ('No_DR', 'Mild', 'Moderate', 'Severe', 'Proliferate_DR') with high precision, demonstrating effective image analysis capabilities. The system's prediction latency is within the target of 5 seconds, ensuring real-time response for individual images. It also handles multiple concurrent users efficiently without compromising performance.

The web application is user-friendly, with clear navigation for uploading images and receiving predictions. Error messages are informative, guiding users in case of issues like invalid file types or login failures.

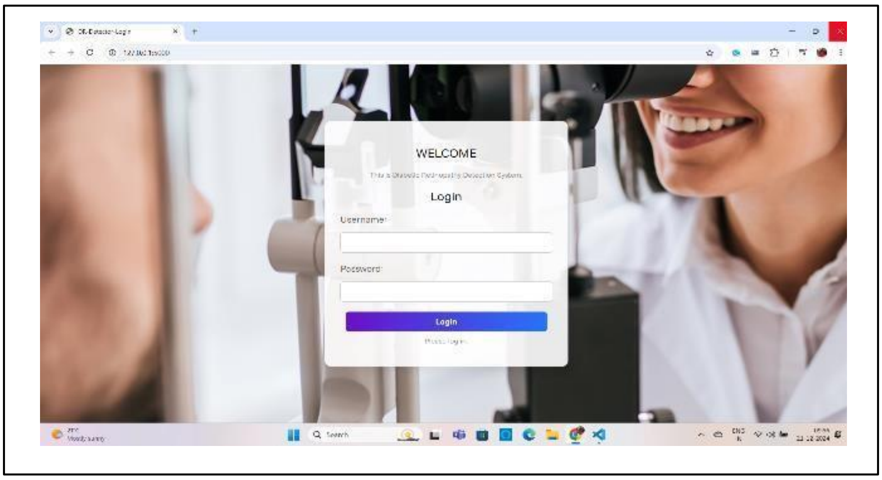

Fig. 2: Login Page

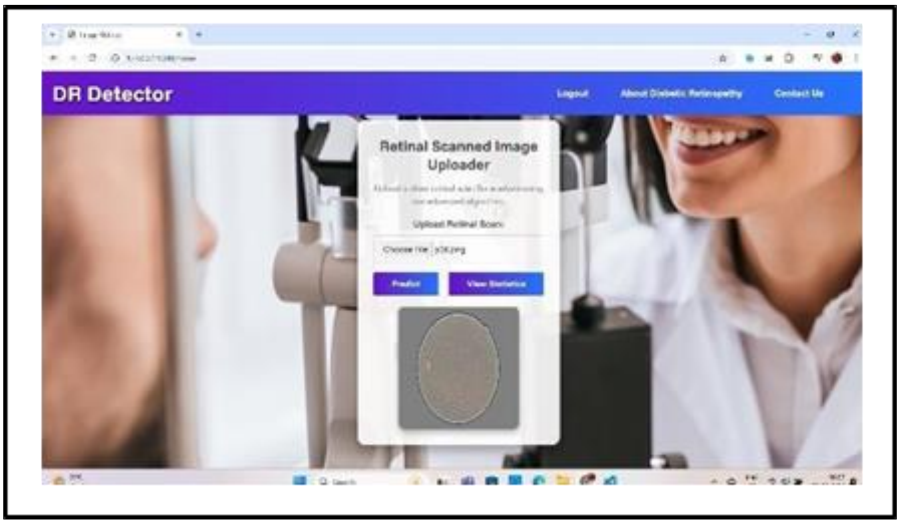

Fig. 3: Image Upload

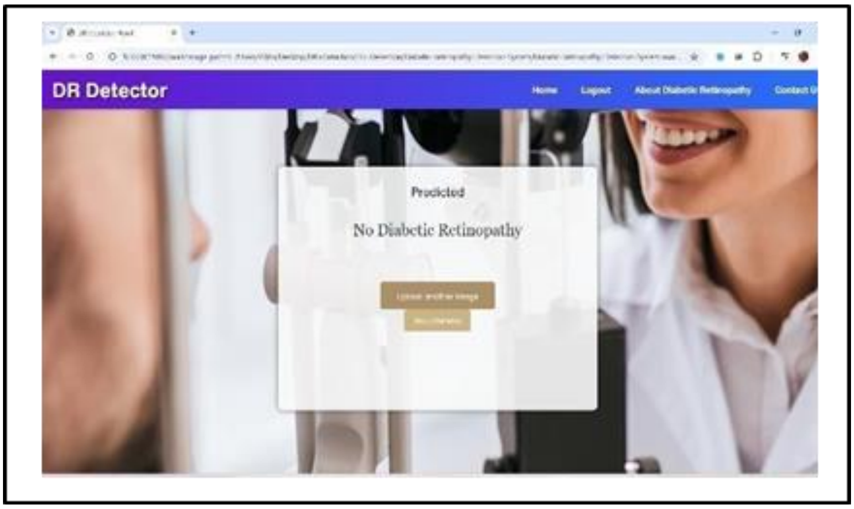

Fig.4. Prediction

The system meets all functional and non-functional requirements, ensuring it is reliable, secure, and capable of deployment in real-world medical environments for diabetic retinopathy detection. The system stores the prediction data in an active csv log file providing analytics to users.

V. CONCLUSION AND FUTURE SCOPE

Conclusion: The Diabetic Retinopathy Detection System uses deep learning and CNN for classifying the severity of diabetic retinopathy from retinal fundus images. With robust preprocessing and a userfriendly Flask web app, the system provides accurate, scalable, and efficient early detection. It bridges manual diagnosis and automated healthcare, helping reduce ophthalmologists' workload while enhancing diagnostic accuracy, particularly in resource-limited areas.

Future Scope: Future improvements include using larger, diverse datasets for better accuracy, real-time video analysis, cloud deployment, and multilingual support. Incorporating explainable AI (XAI) for transparency, advanced visualization like heatmaps, and expanding to detect other retinal conditions (e.g., glaucoma) can enhance the system's clinical value and global accessibility.

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