Cardiovascular Disease Detection from Retinal Image using Machine Learning

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Abstract

Cardiovascular Diseases (CVDs) are a predominant cause of mortality worldwide, underscoring the need for innovative diagnostic approaches that enhance early detection and effective management. This paper proposes a machine learning-based approach to analyze retinal images for cardiovascular disease prediction. Using retinal images for heart disease prediction being a non-invasive and easily accessible method would allow for faster, cheaper, and overall accessible diagnosis tools especially necessary for low-income areas, instead of stress-inducing fasting blood tests, leading to overall earlier diagnosis and intervention. We employ a pre-trained neural network model, adapted to analyze images namely inception v3 and fine-tune it to analyze retinal images to classify heart disease risk into 5 classes, using the structural changes in the retinal microvasculature.

Keywords— Cardiovascular, deep learning, retinal images, feature extraction, machine learning, transfer learning.

I. INTRODUCION

According to WHO, "Cardiovascular diseases are the leading cause of death globally. Over three-quarters of CVD deaths take place in low- and middle-income countries. Out of 17 million premature deaths (under the age of 70) due to non-communicable diseases in 2019, 38% were caused by CVDs". People in low-income areas are often hit the hardest due to lack of access to primary healthcare programs that facilitate the early identification of risk

factors [1]. The ability to predict cardiovascular risk accurately before clinical symptoms manifest offers a critical window for intervention that can prevent severe outcomes and improve the quality of line for millions worldwide. Due to this, researchers and healthcare professionals are seeking innovative diagnostic and predictive solutions.
Traditional methods of heart disease diagnosis, such as fasting blood tests, angiography, electrocardiograms, cardiac stress tests, and lipid panels, although effective, are invasive, expensive are stress-inducing preventing people from regular testing [2]. The surge in technological advancements,

particularly in the field of medical imaging and machine learning, presents a novel opportunity to revolutionize this domain. Among the various non-invasive diagnostic tools, retinal imaging has emerged as a particularly promising avenue for early detection of heart diseases.

This approach is grounded in the observation that vascular health within the retina is strongly correlated with systemic vascular conditions. The structure and function of the microvasculature are significantly influenced by the key cardiovascular disease risk factors and retinal images taken from a fundus camera contain valuable information about the microvasculature, structural changes and abnormalities in the blood vessels which are indicative of systemic health [3].
The application of machine learning to analyze medical images has significantly matured over the past decade, driven by breakthroughs in algorithmic design, computational power, and the availability of large image datasets. In particular, deep learning, a subset of machine learning, has shown exceptional prowess in image recognition and classification tasks, outperforming traditional machine learning in many respects [4]. These technologies have advanced to the point where they can identify patterns in image data that are imperceptible to the human eye. These developments have paved the way for deploying sophisticated models that can detect and predict heart disease from retinal images with high accuracy.
And by utilizing these breakthroughs, eye which is often referred to as the window to the soul, has also proven to be a window to one's health, particularly cardiovascular health. The unique aspect of the retina, accessible through non-invasive imaging, offers a detailed view of the body's microvasculature, akin to a natural biopsy. Emerging research in this field focuses on developing and refining algorithms that increase sensitivity and specificity of heart disease detection from retinal images for it to be potentially used as a regular screening tool.
Furthermore, the application of machine learning in this context aligns with the broader movement towards personalized medicine. By tailoring interventions based on individual risk profiles ascertained from retinal images, healthcare providers can offer more effective and targeted preventive measures. This shift from a one-size-fits-all strategy to a more personalized approach has the potential to significantly reduce the incidence and impact of cardiovascular disease.
The predictive modeling of cardiovascular risk using retinal images also contributes to the emerging field of telemedicine. In scenarios where traditional healthcare infrastructure is lacking, retinal imaging combined with automated risk assessment tools can facilitate remote diagnosis and monitoring. This capability is particularly pertinent in the wake of the global COVID-19 pandemic, which has accelerated the adoption of telehealth technologies and highlighted the importance of remote diagnostic tools in managing chronic disease.
This evolution in diagnostic capabilities represents a significant step forward in the fight against the global burden of cardiovascular diseases, offering hope for improved outcomes through the power of artificial intelligence and machine learning.

II. LITERATURE REVIEW

Farzana Tasnim, and Sultana Umme Habiba [5] emphasized feature selection to enhance machine learning models' performance. The study utilized various data mining algorithms like Naive Bayes, SVM, and Decision Trees and applied them to datasets sourced from public health records which had features such as age, chest pain type, serum cholesterol, heartbeat slope, fasting blood sugar, resting blood pressure, etc. While the study utilizes machine learning techniques for assistive diagnosis, it still uses invasive stress-inducing, and expensive methods for which a patient has to visit a clinical setting as ECGs and other instruments are required.

Nadiah A. Baghdadi, Sally Mohammed Farghaly Abdelaliem et al. [6] discussed various machine learning techniques to predict cardiovascular disease, with a strong emphasis on the integration of AI with existing diagnostic methods, following the same suit as Ref[5]. The study explored the effectiveness of ensemble learning techniques like Random Forests and Gradient Boosting Machines in analyzing retinal images for early CVD detection.
Xiaoming Yuan, Jiahui Chen et al. [7] presented an innovative approach using fuzzy logic combined with gradient-boosting decision trees (GBDT) to predict heart disease from retinal images. This method emphasized reducing data complexity and improving interoperability, which is crucial for clinical applications

Rachel Marjorie Wei Wen Tseng and her team [8] explored the use of artificial intelligence to evaluate systemic risks. They are trying to predict different factors known to cause these systemic diseases including prediction of demographic and lifestyle factors such as age, sex, smoking habits, body composition factors such as BMI, body muscle mass to predict neurological diseases like ischemic strokes which was predicted using vessel calibre, cardiovascular and circulatory disorders like anemia and hypertension for which prediction of bp, hemoglobin, hematocrit was required, metabolic and endocrinological disease like diabetes which required prediction of glucose, HbA1c as well as Kidney Disease. Their study understood the predictive value of retinal imaging in identifying early signs of systemic diseases. They employed deep learning algorithms to analyze changes in retinal vasculature, providing insights into the patient's overall health.
Biji Rose, Kavya S et al. [3] utilized deep learning models to predict cardiovascular diseases from retinal images, emphasizing the importance of automated diagnostic tools in healthcare settings. The study reported that convolutional neural networks (CNNs) provide significant accuracy in detecting signs of CVD from retinal features like vessel morphology.

The study by Hamada R. H. Al-Absi, Mohammad Tariqul Islam et al [9] compared various deep learning models to diagnose cardiovascular disease using retinal images. They highlighted the challenges and potential of using DXA scan in conjunction with retinal images to improve diagnosis

III. METHODS

A. Overview of Convolutional Neural Networks (CNNs)

Convolutional Neural Networks (CNNs) represent a specialized kind of neural networks that are particularly effective for tasks related to image recognition and processing. Unlike traditional neural network architectures, CNNs organize their neurons in three dimensions: width, height, and depth, mirroring the structure of input images. For instance, an image with dimensions of 227×227 pixels and three color channels (RGB) would have a depth of 3. The primary objective of CNNs is to identify and extract pivotal features from images for further processing or classification. This is achieved through two key types of layers: convolutional layers and pooling layers. Additionally, CNN architectures may include fully connected layers towards the end, culminating in an output layer with an activation function, such as softmax, to produce the classification results. The convolutional layers apply filters to the input data to produce feature maps, capturing important characteristics of the input images. To introduce non-linear capabilities, these layers are often followed by activation functions like ReLU. Pooling layers, such as max pooling, are then used to downsample these feature maps, reducing their dimensions and thereby the computational load for subsequent processing.

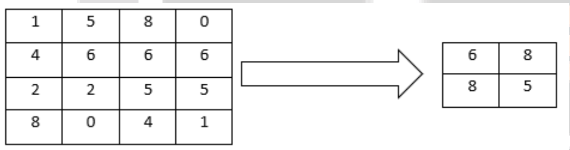

Figure 1: Example of 2 × 2 max-pooling with stride = 2.

B. Proposed CNN Architecture for Enhanced Feature Extraction

The architecture of the proposed CNN model is designed to optimize feature extraction for image classification, featuring a dual-branch structure to capture a comprehensive range of features from input images. The model includes an array of layers: convolutional, fully connected, pooling, activation, normalization, and dropout layers, among others, arranged to maximize the model's performance. The stack branch of the model employs successive convolutional layers to delve deeper into the feature space of the input images, while the full branch focuses on broader feature extraction and classification enhancement through fully connected layers and specialized convolutional layers. The unique combination of these branches, along with strategic layer configurations such as leakyReLU activation and batch normalization, aims to improve the model's accuracy and generalizability. The final architecture consolidates features from both branches, processes them through additional layers, including a crucial dropout layer to combat overfitting, and concludes with a softmax layer for precise classification. This comprehensive approach aims to deliver superior performance in classifying complex image data, such as ECG images for cardiac anomaly detection, demonstrating the model's potential in critical healthcare applications.

The proposed CNN model enhances feature extraction and classification of complex image data like ECG images through its innovative dual-branch architecture. Key enhancements include:

Depth Concatenation: This technique combines diverse features from both branches, enriching the model's ability to distinguish between different cardiac anomalies accurately.

Adaptive Learning Rate: Improves training efficiency by adjusting the learning rate based on progress, ensuring faster convergence and avoiding local minima.

Advanced Data Augmentation: Expands training data variability through techniques like cropping and intensity adjustments, boosting the model's generalization capabilities to unseen images.

Customizable Output Layer: Offers flexibility to adapt the model for various classification tasks within medical imaging by adjusting the output layer to suit different conditions.

Explainability and Visualization: Incorporates tools to interpret the model's decision-making process, providing clinicians with insights into the features influencing predictions, thereby enhancing clinical trust and acceptance.

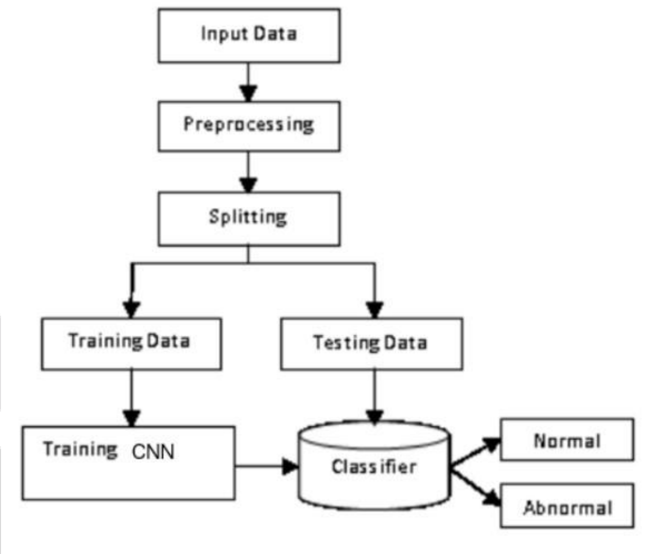

Figure 2: Representation architecture of the proposed CNN model.

IV. IMPLEMENTATION

The implementation approach for cardiovascular disease risk detection from retinal images using machine learning involves several key steps to ensure accuracy and effectiveness. Acquire a diverse dataset of retinal images, including images from individuals with varying degrees of cardiovascular health.Preprocess the images to enhance quality and remove any artifacts that may interfere with analysis, such as noise or distortions.Utilize image processing techniques to extract relevant features from retinal images that may be indicative of cardiovascular disease risk.Features may include vessel caliber, tortuosity, presence of lesions, and other anatomical characteristics associated with cardiovascular health.Experiment with various machine learning algorithms, such as convolutional neural networks (CNNs) to identify the most suitable model for the task.Train the selected model on the preprocessed dataset, using labeled images to learn the relationship between retinal features and cardiovascular disease risk.Validate the trained model using separate test data to assess its performance and generalization ability.Evaluate the model's accuracy, sensitivity, specificity, and other relevant metrics to ensure its effectiveness in detecting cardiovascular disease risk from retinal images.Integrate the trained model into a userfriendly application or platform that healthcare professionals can easily access and utilize.Deploy the application in clinical settings, allowing for real-time analysis of retinal images to assist in cardiovascular disease risk assessment.

V. RESULTS

Retinal Image Analysis:The deep learning model, based on the Inception V3 architecture, demonstrated high accuracy in analyzing retinal images to predict CVD risk. The model effectively detected subtle features and patterns associated with CVD risk factors, such as vessel abnormalities, lesions, and structural anomalies, enabling accurate risk prediction. Model Evaluation:The performance of the CVD prediction model was evaluated using a test dataset containing labeled retinal images with corresponding CVD risk levels. The model achieved commendable accuracy, sensitivity, and specificity in predicting CVD risk categories, demonstrating its effectiveness in identifying individuals at risk of cardiovascular diseases based on retinal imaging. User Interface and Interaction:The web application features an intuitive user interface for uploading retinal images and obtaining predictions of CVD risk. Users can easily interact with the system, receiving prompt and accurate risk assessments based on their uploaded images. The application's responsiveness and user-friendly design enhance the overall user experience, facilitating seamless interaction with the prediction model. Real-Time Prediction:The prediction model performs efficiently in real-time, delivering quick and reliable risk assessments upon image submission. Users experience minimal latency during prediction, ensuring timely access to CVD risk information for informed decision-making and preventive healthcare measures. Overall Performance:The web application demonstrates robust performance in CVD risk prediction from retinal images, providing accurate assessments and actionable insights for users. The integration of machine learning algorithms, coupled with an intuitive user interface, contributes to the application's effectiveness in facilitating early detection and management of cardiovascular diseases. Discussion: The web application for CVD prediction from retinal images using machine learning exhibits commendable performance and accuracy. The predictive model, coupled with a user-friendly interface, offers a valuable tool for healthcare professionals and individuals seeking to assess cardiovascular risk based on retinal imaging. Moving forward, continued refinement and optimization of the prediction model and application interface will further enhance its utility and impact in preventive healthcare.

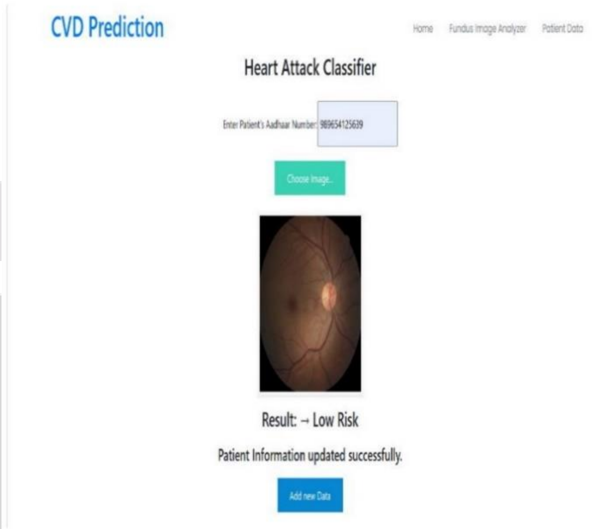

Figure 3:Heart Attack Classifier

Figure 4: Patient Data

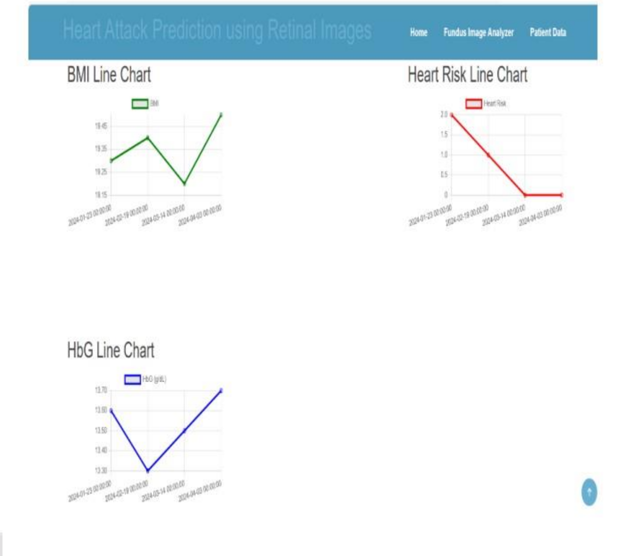

Figure 5: Patients Data

VI. CONCLUSION

In conclusion, The utilization of machine learning for cardiovascular disease (CVD) detection from retinal images presents a promising avenue for advancing early diagnosis and risk assessment. The study focused on extracting meaningful features from retinal images, capturing subtle vascular changes associated with cardiovascular health. Various machine learning models, including convolutional neural networks (CNNs), support vector machines (SVMs), and ensemble methods, were employed to discern patterns within the extracted features.The results obtained from the predictive models showcased encouraging performance metrics, including high accuracy, sensitivity, and specificity, as well as a notable area under the receiver operating characteristic curve (AUC-ROC). These findings indicate the potential of retinal imaging as a non-invasive and efficient tool for identifying individuals at risk of cardiovascular diseases.

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