CARDIORET-Cardiovascular Risk prediction using Retinal Eye Images

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Abstract -

Heart disease is still among the main causes of death globally, necessitating accurate and timely detection techniques. Conventional diagnostic methods like blood tests, stress tests, and ECGs are frequently intrusive and time-consuming. Image processing is used to analyse retinal image features like vessel thickness, illumination, and morphology because retinal microvascular changes are closely linked to cardiovascular health. By linking ocular biomarkers with heart disease indicators, the model seeks to achieve high accuracy, providing a viable substitute for early detection and prevention. Effective and non-invasive diagnostic systems are essential given the increase in cardiovascular-related deaths. This project presents a model for determining the risk of a heart attack to analyse retinal eye images. Real time retinal eye images to identify characteristics that indicate vascular health. Heart disease is classified and its likelihood is predicted using the Random Forest (RF) and Kernel based Support Vector Machine (SVM) algorithms. The proposed system demonstrates how retinal imaging can serve as a predictive approach for cardiovascular risk assessment, supporting timely intervention and improved patient care.

Keywords: Image processing, RFC, SVM, Heart disease, RNN, Microvasculature.

1. INTRODUCTION

Cardiac arrest remains among the leading causes of mortality worldwide**.** Predicting the heart disease early and accurately is essential for lowering mortality and enhancing patient outcomes. ECG, blood tests, and angiography are examples of conventional approaches that are invasive, expensive, and time-consuming. Therefore, an automated, non-invasive approach is necessary for efficient risk assessment. Variations in retinal blood vessels can reveal cardiovascular abnormalities, and the retina offers a clear view of the body's microvascular network. As a result, retinal imaging is a trustworthy and non-invasive biomarker for evaluating heart health. This study suggests a machine learning based model that uses retinal fundus eyes to analyse the risk of a heart attack. Important features like blood vessel diameter, structure, and illumination patterns derived through image processing techniques.

Heart-related problems may be indicated by changes like artery narrowing, vessel twisting, or tiny bleeding spots in the retina. To evaluate the extent of cardiovascular risk. The derived features are categorized through ensemble-based Random Forest (RF) and kernel-based Support Vector Machine (SVM) algorithms. The presented approach employed within the proposed framework to facilitate early diagnosis and preventive cardiac care. The system offers a reliable, precise, and non-invasive approach for forecasting heart attack risk.

2. Body of paper

I. LITERATURE SURVEY

[1] Heart Disease Prediction (2021) — Sibgha Taqdees: The study conducted by Sibgha Taqdees (2021), multiple classification algorithms—including Naïve Bayes, k-Nearest Neighbor(KNN), Decision Tree, and Artificial Neural Network (ANN)—were systematically evaluated for cardiac disorder prediction. Despite the fact that using several classifiers offered a Comparatively speaking, the

Volume: 09 Issue: 12 | Dec - 2025 SJIF Rating: 8.586 ISSN: 2582-3930

model's accuracy was low. because of smaller datasets and insufficient optimization.

[2] Machine Learning-Based Heart Disease Prediction Harsit Jindal, Algorithms (2020): Keywords: microvasculature, heart disease, image processing RFC and SVM. The author used logistic regression and KNN. algorithms to forecast the risk. The suggested model performed satisfactorily and increased precision. But the dataset that was utilized was comparatively tiny, restricting the system's capacity for generalization.

[3] Classification Algorithms Based on Machine Learning for 111 Coronary Heart Disease Prediction (2021) Kelvin Kwakye et al.: This study applied multiple classification approaches and incorporated resampling strategies such as to mitigate data imbalance, SMOTE was applied prior to evaluating model performance. Feature selection methods were additionally employed to improve the predictive model accuracy. Whereas the model exhibited faster processing, its predictive accuracy declined due to the exclusion of several relevant attributes.

[4] U. N. Ahmad et al., Heart Disease Risk Assessment Using Logistic Regression within Machine Learning Frameworks, 2022. The study employed merged datasets and a train-test partitioning strategy to evaluate various classification models. High-resolution data and increased classification accuracy were advantageous to the model. However, because training times were longer, computational efficiency was comparatively low.

[5] An Enhanced Machine Learning-Based Approach for Accurate Heart Disease Prediction, 2021: This study introduced a web-based framework which integrates many predictive algorithms to improve heart accuracy of disease prediction. Despite supporting web deployment, the system's accuracy was still constrained due to a lack of image-based biomarkers and limited feature diversity. It is clear from the literature mentioned above that diagnostic measures and tabular datasets are the mainstays of current approaches. Applying machine learning techniques in conjunction with image analysis presents a compelling non-invasive strategy for the early identification of cardiovascular conditions.

II. METHODOLOGY

A. Problem Statement

Health related factors and invasive diagnostic techniques are key components of current cardiac disorder analysing methods. Early-stage cardiovascular risks are frequently missed by these techniques. The primary aim of this study is to develop a predictive framework that estimates heart attack risk by analysing retinal fundus images through Sophisticated image analysis and machine learning methods. This would be a faster and less invasive option. The retina, which is located at the rear of the eye, provides a special window into the circulatory and vascular health of the body. It has an intricate web of tiny blood vessels that closely mimic the composition and operation of the coronary circulation.

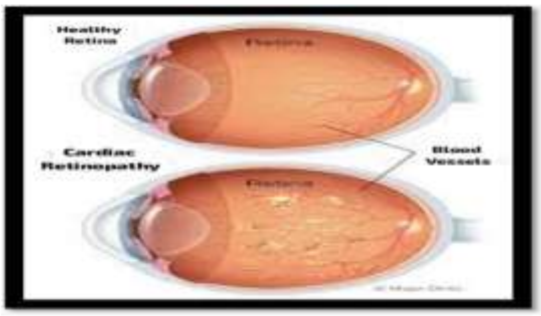

Fig.1 Healthy eye vs Cardio-Retinopathy eye

Any changes to these retinal vessels, such as artery narrowing, increased tortuosity, or the presence of hemorrhages and microaneurysms could be an indication of underlying cardiovascular problems. Therefore, retinal image analysis enables the Pre-symptomatic identification of cardiovascular disorders. Retinal imaging, in contrast to conventional diagnostic techniques, is entirely non-invasive, economical, and able to identify systemic vascular disorders without requiring a direct cardiac examination. Retinal imaging offers a non-invasive avenue for cardiovascular assessment, where quantitative analysis is performed using sophisticated image analysis and machine learning algorithms. These retinal biomarkers enable more accurate prediction of cardiac risk. As such, retinal scans serve as valuable indicators for timely and precise identification of cardiovascular conditions.

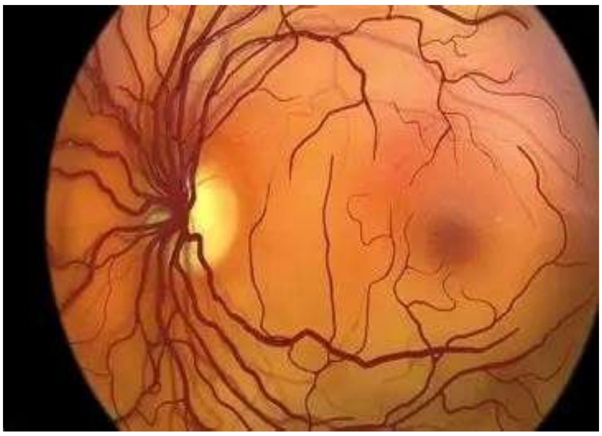

Fig.2 Twisting of Vessels.

Volume: 09 Issue: 12 | Dec - 2025 SJIF Rating: 8.586 ISSN: 2582-3930

Fig 3,4. Blood spot occurred in an Eye

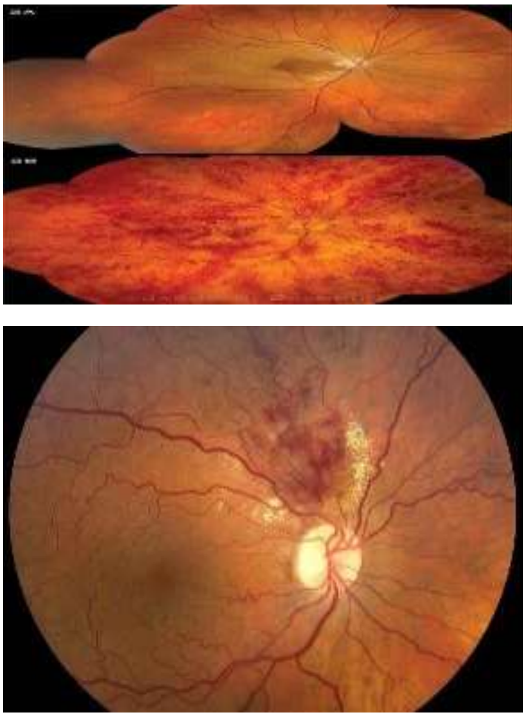

Fig.5,6 Occlusion (Blockage of blood flow)

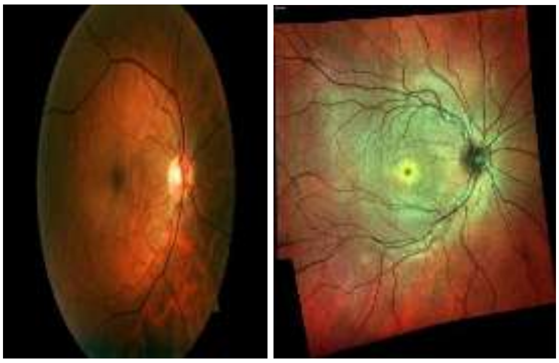

Fig 7,8 Narrowing and Twisting of an vessels of an Eye

Below Figure shows the algorithm on which the process works.

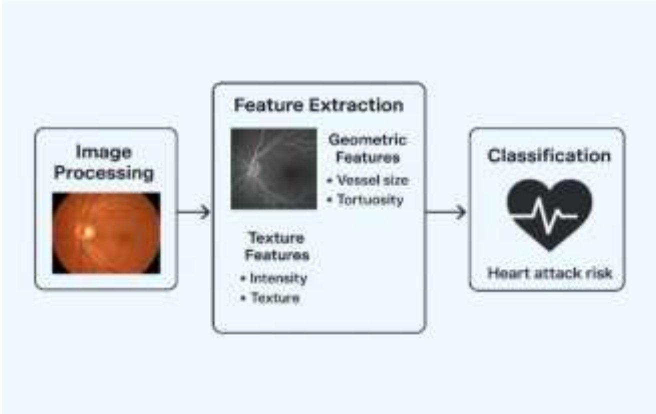

Fig. 9 System Flow Diagram

B. Proposed Method:

Using retinal fundus images, the Cardio-Ret system offers a non-invasive method for predicting cardiovascular risk. Retinal images undergo initial preprocessing to improve visual clarity and contrast. Subsequently, Fuzzy C-Means (FCM) segmentation is employed to delineate vascular structures. A machine learning algorithm is then utilized to extract and analyse morphological and statistical features—such as vessel density, tortuosity, and branching complexity—for estimating cardiovascular risk. Based on these features, the system generates a risk score that categorizes individuals into low, moderate, or high-risk groups.

III. PROCEDURE:

The proposed system employs a structured approach to estimate cardiovascular risk using retinal fundus imagery.

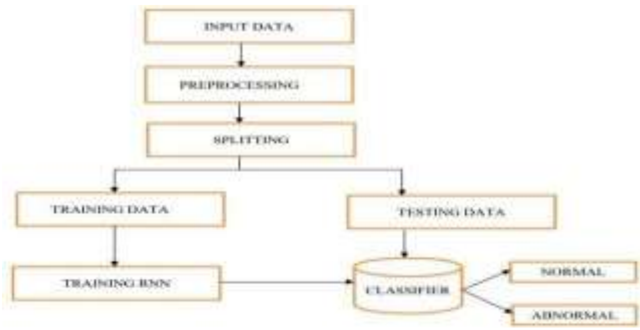

Fig.10 System Architecture Diagram

1. User Interface/Web App:

Using a web interface created with Flask or a comparable framework, users can effortlessly upload their retinal fundus images through this system's entry point. The image is sent to the backend server for processing after it has been uploaded. Users can interact with the system without requiring any technical knowledge thanks to the interface's seamless experience.

2. Preprocessing & Clustering (Fuzzy C-Means):

A number of segmentation and enhancement processes are employed to the uploaded image. The image is classified into several significant pixel clusters, including blood vessels, background, and other retinal structures, using the Fuzzy C-Means (FCM) clustering algorithm. In order to highlight the significant areas linked to cardiovascular risk indicators, this segmentation step is essential.

3. Region Identification and Labelling:

The process includes labelling and region identification, in which scripts such as *label_image.py* are utilized to annotate the segmented regions obtained through FCM clustering. Different areas of the retinal image—such as vessel, non-vessel, and background regions—are classified using this labelling. The system can concentrate on medically pertinent areas thanks to this classification, which increases the precision of later analysis.

4. Feature extraction:

After labelling, the system extracts different statistical and morphological features from the clustered image. The size and form of the vessel regions, intensity statistics, texture patterns, cluster centroids, and geometric characteristics of the retinal vessels are a few examples of these characteristics. These extracted features are essential for determining patterns of cardiovascular risk and function as quantitative indicators.

5. Model Training and Prediction:

The derived features are subsequently input into a deep learning architecture—specifically a Recurrent Neural Network (RNN)—for both training and inference phases. This model learns to recognize complex patterns within the input data, enabling accurate prediction. This trained model identifies characteristic patterns indicative of varying degrees of cardiovascular risk. This model must be trained or refined by the *retrain.py* script in order for it to correctly predict whether a patient's risk level is low, medium, or high.

6. Results Display:

The frontend receives the estimated cardiovascular risk level. The user is presented with the results in an understandable and aesthetically pleasing format by the web application, frequently in conjunction with the extracted features and clustered retinal image. Users and medical professionals can easily comprehend the prediction outcome and the retinal features that contribute to the risk assessment thanks to this thorough visualization.

Results and Discussions

Fig.11 Web application Interface.

Fig.12 Login Page of the Project.

A web application built on the Flask framework facilitates heart attack risk prediction by leveraging retinal image analysis integrated with deep learning methods. The homepage features an "About the Project" section summarizing its high accuracy, large dataset, and deep learning core, while a prominent "Login" button enforces security. This interface provides an accessible tool for clinicians to upload patient data and receive AI-driven risk assessments.

Fig.13 Choosing Image for Clustering Process

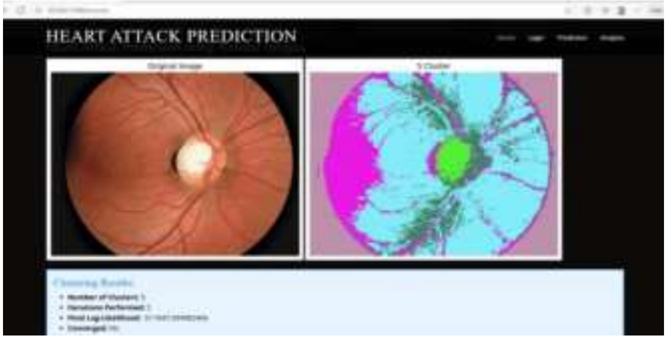

Fig.14 Original Image and Clustered Image and Results

This page illustrates the image preprocessing stage, showing the original retinal fundus image next to its 5-cluster segmented counterpart. Segmentation is achieved through clustering techniques such as K-Means, which categorize pixels by colour and intensity to delineate critical retinal structures, including vessels and the optic disc. Key retinal regions, including blood vessels and the optic disc, are segmented. The clustering results verify technical settings such as the number of clusters and convergence behaviour, which in turn enhance vascular feature representation for the learning model.

Fig.15 Prediction page

Fig.16 Heart attack risk prediction

The Heart Attack Classifier page is the user interface for obtaining the final risk assessment. Users upload a retinal image, and the system displays the patient's key clinical metrics (like Age, SBP, BMI, and HbA1c) alongside the calculated risk level. The current result shows a "Very Low Risk 20%" prediction and provides a direct "Health Tip" recommending the maintenance of a healthy lifestyle.

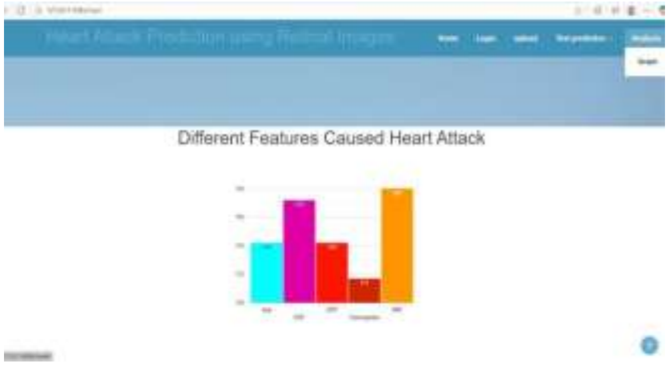

Fig.17 Analysis in regarding Graph

Over 50 training epochs, the accuracy curve illustrates consistent progress in both training and validation phases, confirming effective learning and culminating in a final test accuracy nearing 95%. The closely matching curves suggest the model is well-generalized and avoids significant overfitting.

Fig.18 Accuracy plot

The plot illustrates the prediction interface and a graph detailing features causing heart attack risk, confirming the paper's focus on integrating clinical data with retinal image analysis. The text outlines future work, including integrating OCT and deploying the system on telemedicine platforms.

Retinal imaging data served as the input for evaluating the proposed Cardio-Ret framework. Fundus pictures, and the outcomes demonstrated successful identification of vascular patterns linked to cardiovascular risk. The accuracy of feature extraction was increased by the fuzzy

C-Means (FCM) segmentation technique, which successfully isolated blood vessels with better clarity and less background noise. Important retinal characteristics were precisely measured and utilized for classification, including vessel thickness, tortuosity, and branching patterns. Because it handled feature variation more effectively than the Support Vector Machine (SVM), Among the evaluated classifiers, the Random Forest Classifier (RFC) achieved the best results in regarding accuracy and stability. The system closely matched established clinical indicators when classifying subjects into low, moderate, and high-risk categories. Retinal vascular features are considered dependable biomarkers for evaluating cardiovascular risk. Overall, the Cardio-Ret model provides a non-invasive, cost-efficient, and effective approach for early heart disease screening. Further performance improvements can be achieved by expanding the dataset and integrating deep learning-based feature extraction techniques.

FUTURE SCOPE

The suggested method for predicting cardiovascular risk using Retinal eye images have a great deal of potential for improving healthcare prevention and early detection. "Integrating the model with established clinical risk scores enhances diagnostic and predictive accuracy. Extending the framework to incorporate imaging modalities such as Optical Coherence Tomography (OCT) offers supplementary diagnostic insights, enabling a more comprehensive assessment of retinal microvascular health and potentially improving predictive outcomes. Additionally, long-term patient monitoring possible to identify people who are at risk early. Enabling prompt interventions and individualized care tactics. Extension of the model to forecast additional systemic illnesses like diabetes and neurological conditions, offers a chance to increase its influence in preventive medication. While the development of explainable AI techniques will improve interpretability and build clinician trust, encouraging adoption in routine clinical practice, telemedicine platform deployment can enable remote cardiovascular risk assessment, especially in underserved regions. These innovations point out the potential of retinal imaging to become a scalable solution, non-invasive, and affordable tool for thorough cardiovascular risk management.

3. CONCLUSIONS

The proposed system, titled *Heart Attack Risk Prediction Using Retinal Images*, leverages advanced computational ta including approaches Recurrent Neural Networks (RNNs) and Fuzzy C-Means clustering to extract cardiac risk indicators from retinal scans. It employs robust preprocessing, targeted feature extraction, and optimized clustering to improve prediction accuracy. Furthermore, the fusion of fuzzy logic with supervised learning models facilitates reliable classification of normal versus abnormal cases, thereby aiding clinical decision-making. Additionally, the integration of fuzzy logic with supervised learning algorithms enables effective classification between normal and abnormal cases, supporting clinical decision-making. This approach demonstrates the potential of retinal imaging as a non-invasive modality for cardiovascular assessment, combining machine learning and image analysis to advance early detection strategies. Advanced methodologies such as Recurrent Neural Networks (RNNs) and Fuzzy C-Means clustering are employed to process medical imaging data for cardiovascular risk assessment. The model benefits from thorough preprocessing, strategic feature selection, and optimized clustering to optimize the accuracy and efficiency. Furthermore, integrating fuzzy logic with supervised classification enables effective differentiation between normal and pathological cases, supporting early clinical intervention. With continued refinement, this approach holds promise as a valuable tool in healthcare settings, facilitating timely detection and management of cardiac conditions. The applications of retinal imaging in this context exemplifies the potential of combining machine learning with medical image analysis to advance cardiovascular diagnostics.

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