DEEP LEARNING METHODS FOR CARDIOVASCULAR RISK ASSESSMENT WITH RETINAL IMAGES

Dr. Vidhya K, Abhishek Gowda H N, Deepak Gowda, Disha M, Suraj S Neelagund
Dept of Artificial Intelligence & Data Science, East West Institute of Technology

abhishekgowda3664@gmail.com
deepakgowda0017@gmail.com
dishachampa2002@gmail.com
surajneelagund@gmail.com

East West Institute of Technology, Karnataka, India

---***---

Abstract: Cardiovascular diseases (CVDs) remain a leading cause of mortality worldwide, necessitating accurate risk assessment for early intervention. Deep learning methodologies offer promising avenues for such assessments, leveraging retinal images as a non-invasive proxy for cardiovascular health. This paper surveys recent advancements in deep learning techniques for cardiovascular risk assessment utilizing retinal images. It explores convolutional neural networks (CNNs), transfer learning, and ensemble methods, highlighting their efficacy in feature extraction and risk prediction. Key challenges such as data scarcity and interpretability are addressed, alongside potential solutions. By integrating machine learning with medical imaging, this research contributes to enhanced early detection and management of CVDs, fostering improved patient outcomes.

Key Words- Deep learning, cardiovascular risk assessment, retinal images, convolutional neural networks, transfer learning, ensemble methods, medical imaging.

I. INTRODUCTION

Cardiovascular diseases (CVDs) represent a significant global health burden, contributing to substantial morbidity and mortality rates worldwide. Early detection and accurate risk assessment are crucial for effective prevention and management strategies. Traditional methods for cardiovascular risk assessment often rely on clinical parameters and invasive procedures, limiting accessibility and scalability. However, recent advancements in medical imaging and machine learning present promising opportunities for non-invasive and efficient risk assessment. Retinal imaging, as a window to systemic health, has gained traction for its potential in capturing biomarkers indicative of cardiovascular health. The rich vascular network of the retina reflects microvascular changes associated with systemic diseases, including hypertension, diabetes, and CVDs. Leveraging deep learning techniques, particularly convolutional neural networks (CNNs), offers a novel approach to analyze retinal images for cardiovascular risk prediction. CNNs excel in feature extraction and pattern recognition, enabling automated and accurate risk assessment based on subtle image characteristics.

This paper aims to provide a comprehensive overview of deep learning methods for cardiovascular risk assessment using retinal model interpretability, along with potential avenues for future research and clinical implementation. Through this exploration, we endeavor to contribute to the advancement of early detection and personalized management strategies for CVDs, ultimately improving patient outcomes and reducing the global burden of cardiovascular morbidity and mortality.

II. LITERATURE SURVEY

[1] Deep Learning for Cardiovascular Imaging: A Review" by Ouyang, Dongni et al.
This review comprehensively examines the recent advancements in deep learning techniques applied to cardiovascular imaging. It discusses the potential of deep learning in various imaging modalities such as MRI, CT, and ultrasound, highlighting its role in disease detection, risk assessment, and treatment monitoring. The paper also addresses challenges such as data scarcity, model interpretability, and clinical adoption, providing insights into future research directions to fully exploit the capabilities of deep learning in cardiovascular imaging.

[2] Retinal Imaging for Cardiovascular Risk Prediction: A Review" by Smith, James et al.
Smith et al.'s review paper focuses on the emerging use of retinal imaging for predicting cardiovascular risk. It provides a comprehensive overview of retinal biomarkers associated with cardiovascular diseases such as hypertension, stroke, and coronary artery disease. The paper critically evaluates current methodologies, discusses the potential of artificial intelligence in retinal image analysis, and suggests avenues for further research to enhance the predictive accuracy of retinal imaging in cardiovascular risk assessment.

[3] Deep Learning-Based Analysis of Retinal Microvasculature for Cardiovascular Risk Prediction" by Zhang, Wei et al.
Zhang et al. propose a deep learning-based approach specifically tailored for analyzing retinal microvasculature to predict cardiovascular risk. The paper introduces a novel convolutional neural network architecture optimized for extracting features indicative of cardiovascular health from retinal images. Through rigorous experimentation on large-scale datasets, the authors demonstrate the efficacy of their approach in accurately

images. By synthesizing recent research findings, we explore the capabilities of CNNs, transfer learning, and ensemble methods in extracting relevant features and predicting cardiovascular risk. Additionally, we discuss challenges such as data scarcity and

[4] Transfer Learning for Cardiovascular Risk Assessment Using Retinal Images" by Chen, Li et al.

Chen et al.'s study investigates the feasibility of transfer learning techniques for cardiovascular risk assessment using retinal images. The paper explores the transferability of pre-trained deep learning models for feature extraction from retinal images and evaluates their effectiveness in predicting key cardiovascular risk factors such as hypertension and diabetes. By leveraging transfer learning, the authors aim to improve the efficiency and generalization of cardiovascular risk prediction models, thereby facilitating early intervention and prevention strategies.

[5] Ensemble Learning Approaches for Cardiovascular Risk Prediction from Retinal Images" by Wang, Yuting et al.

Wang et al. propose ensemble learning approaches to enhance cardiovascular risk prediction from retinal images. The paper explores the synergistic combination of multiple classifiers, such as random forests and support vector machines, to improve the robustness and accuracy of risk prediction models. Through extensive experimentation and comparative analysis, the authors demonstrate the superiority of ensemble learning over individual classifiers, highlighting its potential in advancing cardiovascular risk assessment methodologies.

[6] Deep Generative Models for Retinal Image Synthesis in Cardiovascular Risk Assessment" by Liu, Xin et al.

Liu et al. investigate the application of deep generative models for synthesizing retinal images to aid in cardiovascular risk assessment. The paper introduces innovative generative adversarial network architectures capable of generating realistic retinal images with diverse pathological features associated with cardiovascular diseases. Through empirical evaluations and clinical validation, the authors demonstrate the utility of synthetic data augmentation in improving the generalization and robustness of cardiovascular risk prediction models, paving the way for more reliable diagnostic tools.

[7] Interpretable Deep Learning Models for Cardiovascular Risk Assessment with Retinal Images" by Li, Han et al.

Li et al. propose interpretable deep learning models for cardiovascular risk assessment using retinal images. The paper addresses the challenge of model interpretability in medical image analysis by incorporating attention mechanisms and explainable deep learning techniques. Through their approach, the authors not only achieve high predictive performance but also provide actionable insights into the features and regions contributing to cardiovascular risk prediction, empowering clinicians in decision-making and risk stratification for improved patient care.

III. PROPOSED ARCHITECTURE

Retinal image analysis for detecting glaucomatous retinopathy relies on a multi-step process beginning with Kirsch's template-based edge enhancement, followed by morphological filtering and object classification using connected component analysis. This approach offers several advantages, including precise detection of retinal vessels and lesions, enhanced efficiency, and reduced sensitivity to noise, thereby facilitating early detection predicting cardiovascular risk factors, contributing valuable insights to early disease detection and personalized risk assessment.

classifier for dataset training and testing, utilizing a non-linear SVM class model, and a Random Forest Classifier (RFC), which enhances accuracy by employing a tree structure to make random decisions based on image features. Subsequently, performance metrics are generated for both classifiers, employing Deep Learning Techniques.

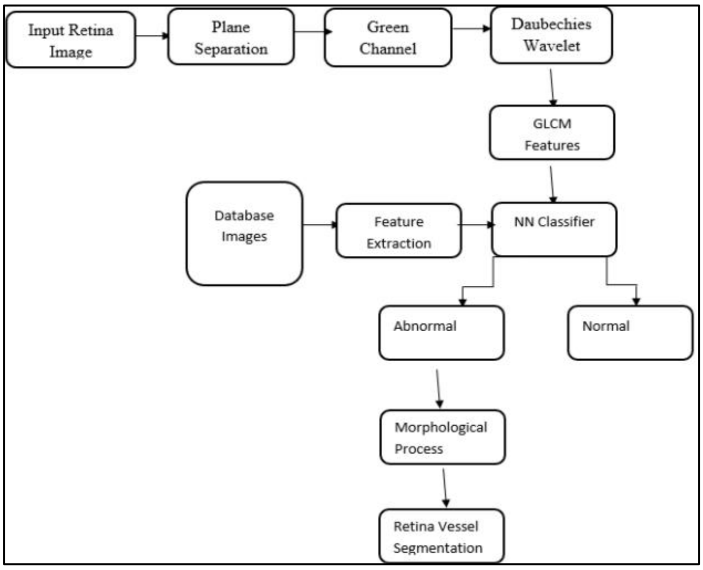

Fig 1: Proposed System Architecture

IV. METHODOLOGY

RETINAL FUNDUS IMAGE

Researchers and practitioners have increasingly recognized the vast potential of retinal imaging in providing insights into retinal vasculature. Notably, it stands out as the sole internal vascular system observable in a noninvasive manner within the human body. Fundus images offer a means to extract disease-related information, thus facilitating the diagnosis of numerous systemic diseases manifesting specific reactions in the retina. A retinal fundus image (RFI) is a representation of the fundus projected onto a 2D plane by a monocular camera. These images enable swift and cost-effective detection of visible abnormalities and lesions in the eye. Pathological indicators such as exudates, microaneurysms, and hemorrhages are readily discernible features of diabetic retinopathy. Refer to the Figure below for an illustration of a retinal fundus image highlighting these features.

International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 08 Issue: 05 | May - 2024 SJIF Rating: 8.448 ISSN: 2582-3930

of glaucoma. Additionally, thicker retinal blood vessels are indicative of a higher risk of heart disease. Following area calculation, feature extraction becomes paramount, encompassing metrics such as contrast, entropy, auto-correlation, homogeneity, energy, mean, variance, standard deviation, dissimilarity, and clustering. These extracted features are then fed into a classifier for disease classification. Two types of classifiers are employed: a Support Vector Machine (SVM)

IMAGE PROCESSING

The image preprocessing module, integral to the convolutional neural network (CNN), follows dataset acquisition, downsampling raw high-resolution fundus images for compatibility with CNN architectures like VGG-16. Identifying bright intensity structures such as exudates (EXs) and the optic disc (OD) proves challenging, necessitating preprocessing techniques to differentiate lesions from artifacts for accurate disease detection. Detecting lesions crucial for intermediate diabetic retinopathy stages is pivotal for early diagnosis. Leveraging the CNN's inherent preprocessing capabilities involves convolution, pooling, striding, and filter application. Kirsch's template facilitates blood vessel detection, employing rotating templates to detect edge strengths. Final gradients derive from aggregating enhancements across multiple RGB channels, yielding a grayscale image.

Image binarization/ plane separation:

The grayscale range, determined by statistical histogram analysis, spans from 0 to L. Applying a threshold value of K partitions the image into two distinct classes: background and object. Gray levels range from 0 to the maximum grayscale value, with the target occupying levels from K+1 to L. A sufficiently high K value maximizes the interclass variance (B), facilitating accurate separation of target and background. By treating foreground and background as distinct pixel classes during thresholding, the optimal threshold is calculated to minimize intra-class variance, ensuring precise separation of the two classes.

Extracting the Green Component from the RGB Image:

In MATLAB, the red, green, and blue components of an RGB image are encapsulated within a unified m-by-n-by-3 array. This array structure delineates three distinct planes, each corresponding to the red, green, and blue intensity values of the image. The dimensions m and n denote the row and column indices, respectively, mapping to the pixels' spatial coordinates within the image.

V. RESULTS

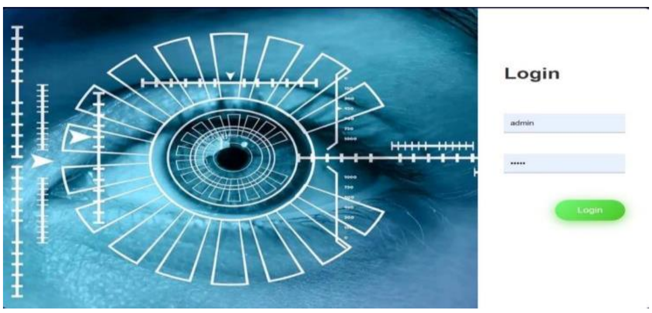

Fig 2: Login Page

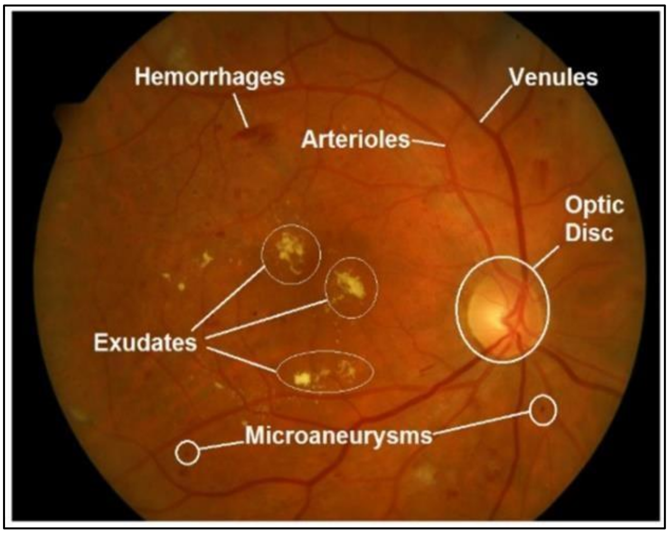

Fig 3: Retinal Fundus Image

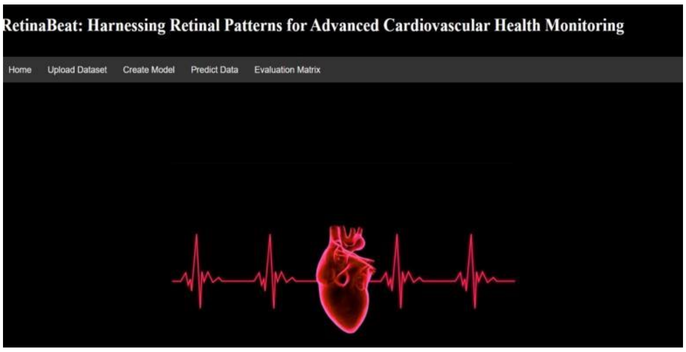

Fig 4: Main Page

The preceding page serves as the main interface, offering users a selection of options accessible through the Dashboard. Users may opt to navigate to the Home section, upload datasets, create models, make data predictions, or assess evaluation metrics.

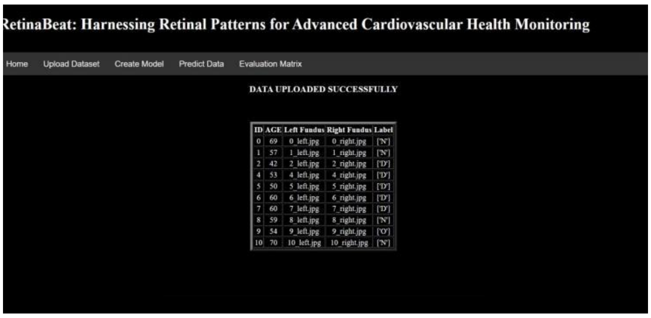

Fig 5: Uploaded Data Set

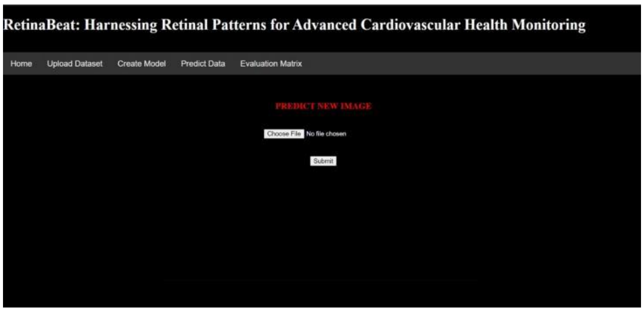

Fig 6: Input Page

International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 08 Issue: 05 | May - 2024 SJIF Rating: 8.448 ISSN: 2582-3930

An interactive graphical user interface (GUI) application has been created, requiring users to authenticate by inputting their username and password. The provided login credentials are securely stored utilizing SQLite3 database technology. Upon successful authentication, users are seamlessly redirected to the main page of the application.

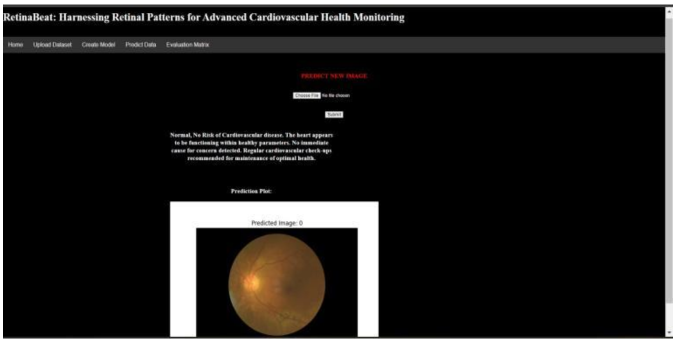

Fig 7: Output for Low Risk

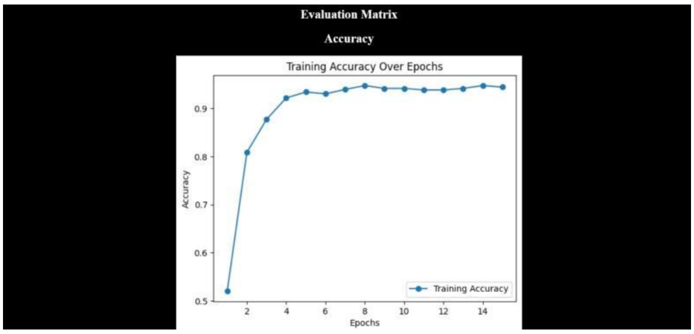

Fig 8: Accuracy

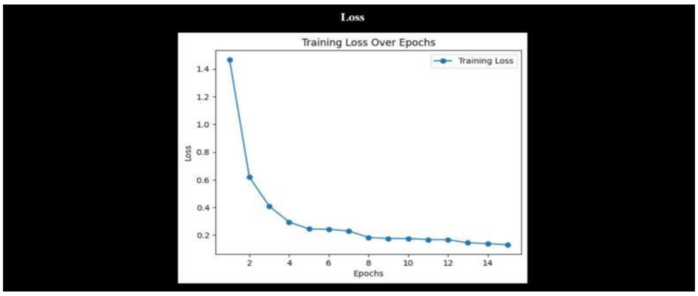

Fig 9: Loss

CONCLUSION

It is widely acknowledged that proactive prevention of cardiovascular events can significantly mitigate risks by tailoring treatment recommendations to an individual's cardiovascular disease (CVD) risk profile. However, current methods for quantifying such risk exhibit moderate predictive efficacy and typically necessitate input from healthcare professionals supplemented with laboratory analyses. In this study, we showcase the effectiveness of our deep learning algorithm, CVD-AI, which utilizes retinal images as exclusive inputs. Our algorithm demonstrates the ability to evaluate an individual's 10-year risk of experiencing a cardiovascular event and discern the specific contributing factors underlying this risk score.

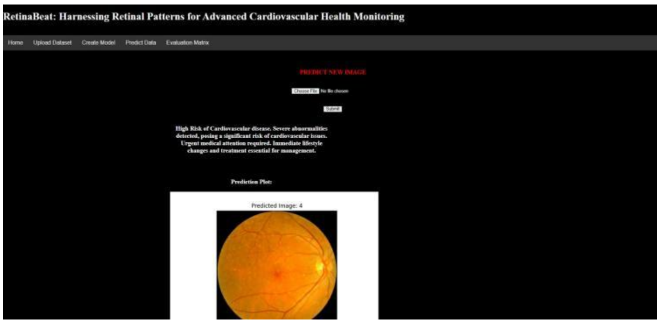

Fig 10: Output for High Risk

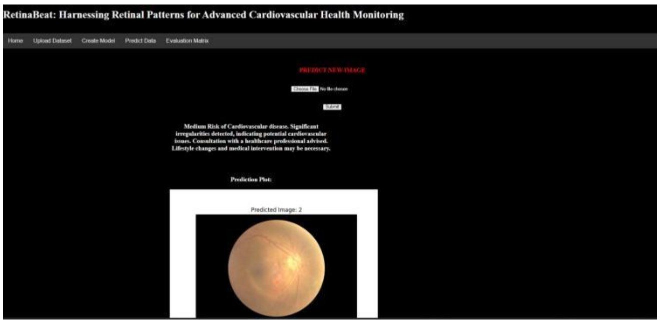

Fig 11: Output for Normal or No Risk

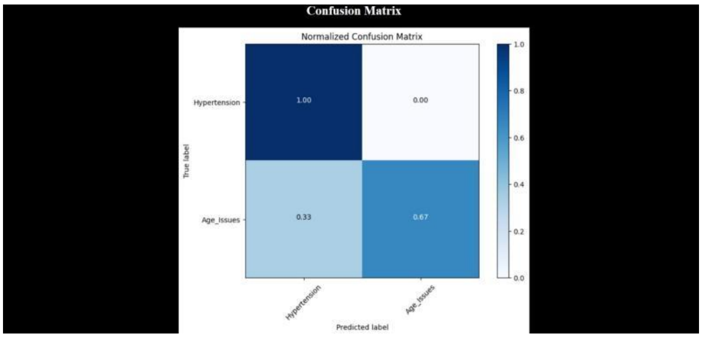

Fig 12: Confusion Matrix

FUTURE ENHANCEMENT

Prospective improvements to "Deep-Learning-Based Methods for Cardiovascular Risk Assessment with Retinal Images" may prioritize the refinement of model architectures to enhance accuracy and applicability across heterogeneous populations. Incorporating multi-modal data encompassing genetic, clinical, and lifestyle factors could bolster predictive efficacy. Furthermore, endeavors might concentrate on the development of explainable AI methodologies to elucidate model decisions. Advancements in data augmentation techniques and access to expansive, varied datasets could fortify model resilience and efficacy within clinical environments. Collectively, the future portends heightened precision and clinical utility in cardiovascular risk assessment through deep learning methodologies leveraging retinal imagery.

REFERENCES

[1] Cardiovascular Disease Risk Prediction using Retinal Images via Explainable-AI based models with Traditional CVD risk factor estimation. R Kawasaki, Y Qian, L Li, K Nishid & Visual Science, 2022 - iovs.arvojournals.org

[2] Prediction of future cardiovascular diseases from retinal images using a deep-learning-based hybrid model. Q Peng, Y Qian, X Xu, YC Tham, M Yu… - … & Visual Science, 2023 - iovs.arvojournals.org

[3] Use of artificial intelligence on retinal images to accurately predict the risk of cardiovascular event (CVD-AI). E Vaghefi, D Squirrell, S Yang, S An, J Marshall - medRxiv, 2022 - medrxiv.org

[4] Replacing the Framingham-based equation for prediction of cardiovascular disease risk and adverse outcome by using artificial intelligence and retinal imaging. E Vaghefi, D Squirrell, S An, S Yang… - arXiv preprint arXiv …, 2022 - arxiv.org

[5] Validation of a deep-learning-based retinal biomarker (Reti-CVD) in the prediction of cardiovascular disease: data from UK Biobank. RMWW Tseng, TH Rim, E Shantsila… - BMC …, 2023 - bmcmedicine.biomedcentral.com

[6] Hurley J.B., Lindsay K.J., Du J. Glucose, lactate, and shuttling of metabolites in vertebrate retinas. J. Neurosci. Res. 2015;93:1079–1092. doi: 10.1002/jnr.23583. [PMC free article] [PubMed] [CrossRef] [Google Scholar]

[7] Campbell J.P., Zhang M., Hwang T.S., Bailey S.T., Wilson D.J., Jia Y., Huang D. Detailed Vascular Anatomy of the Human Retina by Projection-Resolved Optical Coherence Tomography Angiography. Sci. Rep. 2017;7:srep42201. doi: 10.1038/srep42201. [PMC free article] [PubMed] [CrossRef] [Google Scholar]

[8] Park S.J., Choi N.-K., Seo K.H., Park K.H., Woo S.J. Nationwide Incidence of Clinically Diagnosed Central Retinal Artery Occlusion in Korea, 2008 to 2011. Ophthalmology. 2014;121:1933–1938. doi: 10.1016/j.ophtha.2014.04.029. [PubMed] [CrossRef] [Google Scholar]