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Enhanced Cardiovascular Disease Risk Prediction from Retinal Vasculature using DenseNet121 in DR and HR Patients

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ABSTRACT: Cardiovascular disease (CVD) is one of the leading causes of mortality worldwide, and early detection is essential for effective treatment and prevention. Retinal imaging has emerged as a noninvasive method for identifying vascular changes associated with cardiovascular risk. The existing system uses the CVDNet framework based on the ResNet50 architecture to analyze retinal fundus images and predict cardiovascular risk in patients with diabetic retinopathy (DR) and hypertensive retinopathy (HR). Although this approach provides promising results, it may suffer from limited feature reuse and higher parameter redundancy. To address these limitations, the proposed system introduces a DenseNet121–based architecture for improved feature extraction and classification. DenseNet121 enables dense connections between layers, allowing better gradient flow and feature reuse. This architecture reduces the number of parameters while improving learning efficiency. The model analyzes retinal vascular structures and automatically learns discriminative patterns associated with cardiovascular risk. It enhances prediction accuracy and reduces over fitting, especially in medical datasets. The proposed system aims to provide a more reliable, noninvasive, and efficient diagnostic tool for early CVD risk detection. This approach can support clinicians in decision making and preventive care. Overall, the DenseNet121–based system offers improved performance compared to traditional deep learning models.

KEYWORDS*:* Cardiovascular Disease (CVD), DenseNet121, Deep Learning, ResNet-50, Diabetic Retinopathy (DR), Hypertensive Retinopathy (HR).

I. INTRODUCTION

Cardiovascular disease remains a major global health concern, responsible for a significant number of deaths each year. Early detection and preventive strategies are essential to reduce mortality and improve quality of life. Traditionally, cardiovascular risk is assessed using clinical tests such as blood pressure measurement, cholesterol analysis, and electrocardiograms. However, these methods may be invasive, time consuming, or expensive. In recent years, retinal imaging has gained attention as a noninvasive alternative for cardiovascular risk assessment. The retina contains a network of blood vessels that reflect the condition of the body's vascular system. Changes in retinal vasculature are often associated with systemic diseases such as diabetes, hypertension, and cardiovascular disorders. Advances in artificial intelligence and deep learning have enabled automated analysis of retinal images. Deep convolutional neural networks can learn complex patterns directly from medical images without manual feature extraction. The existing system uses the CVDNet model based on the ResNet50 architecture to predict cardiovascular risk from retinal images of patients with diabetic retinopathy and hypertensive retinopathy. While this model achieves good performance, it may not fully exploit feature reuse across layers. DenseNet architectures have been introduced to overcome these limitations by connecting each layer to every other layer, improving information flow and reducing parameter redundancy. This project proposes a DenseNet121–based approach for cardiovascular disease risk prediction from retinal vasculature. The system aims to enhance feature learning, improve prediction accuracy, and provide a reliable noninvasive

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diagnostic tool. By leveraging advanced deep learning techniques, the proposed model can support early diagnosis and assist clinicians in preventive healthcare.

1.1 Objective

The main objective of this study is to develop an advanced system for predicting cardiovascular disease risk using retinal fundus images. The system focuses on analyzing retinal vascular structures in patients with diabetic retinopathy and hypertensive retinopathy. It aims to provide a non-invasive and cost-effective alternative to traditional cardiovascular diagnostic methods. The proposed approach utilizes the DenseNet-121 deep learning architecture for improved feature extraction. Dense connections in the network help in better information flow between layers. This enables the model to capture both low-level and high-level vascular features effectively. The system is designed to reduce parameter redundancy and improve learning efficiency. It also aims to increase prediction accuracy compared to existing models. Another objective is to minimize over fitting, especially in small medical datasets. The model will automatically learn relevant patterns without manual feature engineering. It is intended to support early detection of cardiovascular risk. The system also aims to provide faster and more reliable predictions. It can assist clinicians in making better diagnostic decisions. The overall goal is to enhance preventive healthcare strategies. This approach seeks to reduce cardiovascular disease incidence through early and accurate risk assessment.

1.2 Outcome

The proposed system is expected to deliver more accurate cardiovascular risk predictions using retinal images. By incorporating the DenseNet-121 architecture, the model achieves better feature reuse across layers. This results in improved learning efficiency and reduced parameter count. The system is expected to outperform traditional models such as ResNet-50 in terms of accuracy. It also reduces the risk of overfitting on limited medical datasets. The dense connections improve gradient flow and stabilize training. The model provides a reliable, automated, and non-invasive diagnostic tool. It helps in early detection of cardiovascular disease risk. The system can support clinicians in making informed treatment decisions. It reduces the need for expensive and invasive diagnostic tests. The proposed approach enhances overall prediction performance. It also improves computational efficiency. The system can be extended to other retinal-based disease predictions. It contributes to the development of intelligent healthcare solutions. Overall, the outcome is a more accurate and efficient cardiovascular risk prediction system**.**

II. LITERATURE SURVEY

[2.1] M. Giordani, M. Polese- This paper provides an early and comprehensive look at the foundational use cases and technological pillars that are expected to define sixth-generation (6G) communication networks. The authors explore the evolution from 5G's enhanced mobile broadband, ultra-reliable low-latency communication, and massive machine-type communication towards more ambitious 6G paradigms. Key use cases discussed include the integration of the physical, digital, and human worlds through extended reality (XR), the proliferation of high-fidelity holographic communications, and the expansion of ubiquitous connectivity via massive network deployments. To support these demanding applications, the article identifies and examines several candidate technologies. These include the utilization of terahertz (THz) frequencies for immense bandwidth, the development of intelligent surfaces for dynamic control of the radio environment, and the design of AI-native network architectures. The paper emphasizes that artificial intelligence will not just be an application but a foundational component of the network itself. It also highlights the need for new security and privacy mechanisms in a hyper-connected world. The concept of network slicing is revisited to provide tailored services for a diverse set of 6G use cases. Furthermore, the paper discusses the integration of non-terrestrial networks to achieve global coverage. The authors argue that a shift from a "one-size-fits-all" approach to a more flexible and service-aware network is essential. Energy efficiency and sustainability are also presented as critical design goals for the future network. The paper concludes by outlining a roadmap and the significant research challenges that lie ahead in realizing the 6G vision. It ultimately paints a picture of 6G as a "network of networks" that must be inherently intelligent, secure, and sustainable to meet the unprecedented requirements of future digital experiences.

[2.2] A. S. Valdez-Guerrero, J. C. Quintana-Pérez -This review article offers a detailed examination of the complex biochemical pathways involved in the pathogenesis of diabetic retinopathy (DR) and provides an overview of the current therapeutic landscape. The authors systematically break down the molecular mechanisms triggered by chronic hyperglycemia, focusing on key processes such as the polyol pathway flux, the accumulation of advanced glycation end-products (AGEs), the activation of protein kinase C (PKC) isoforms, and the role of oxidative stress and inflammation. By elucidating how these interconnected biochemical alterations lead to capillary occlusion, increased vascular permeability, and retinal ischemia, the paper provides a strong scientific foundation for understanding the

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clinical manifestations of DR. Following this, the review transitions to a discussion of the main treatment strategies, which are largely directed at managing these underlying pathways. It covers established approaches like strict glycemic and blood pressure control, as well as more targeted interventions such as intravitreal anti-vascular endothelial growth factor (VEGF) agents and laser photocoagulation. The paper effectively links the molecular drivers of the disease to the rationale behind current therapies, while also hinting at potential future therapeutic targets arising from a deeper understanding of these biochemical alterations.

[2.3] T. R. Gadekallu, N. Khare -This study focuses on the application of advanced deep learning techniques for the automated prediction and detection of diabetic retinopathy from retinal images, addressing the need for scalable and accessible screening solutions. The authors propose a novel model that leverages a deep neural network architecture, potentially incorporating techniques like transfer learning and feature optimization to enhance classification performance. The paper details the methodological pipeline, which likely includes preprocessing of retinal fundus images to enhance features, followed by the training and validation of the deep learning model on a publicly available or proprietary dataset. A key contribution of this work is its emphasis on improving the accuracy and reliability of DR detection, moving beyond simple binary classification (DR vs. no DR) to potentially grade the severity of the condition. By achieving high predictive performance, the model demonstrates the potential of artificial intelligence to assist clinicians in large-scale screening programs, reducing the workload on specialists and enabling earlier intervention for patients at risk of vision loss. The research underscores the growing role of ambient intelligence and computational methods in modern healthcare.

[2.4] X.-H. Xu, B. Sun, S. Zhong, -This meta-analysis provides powerful epidemiological evidence for the prognostic value of diabetic retinopathy (DR) beyond its ocular implications, firmly establishing it as an independent predictor of cardiovascular mortality in patients with diabetes. By systematically reviewing and pooling data from multiple longitudinal cohort studies, the authors were able to synthesize a large body of evidence to quantify the relationship between the presence of DR and the risk of death from cardiovascular causes. The study's rigorous methodology, which likely involved assessing study quality and heterogeneity, strengthens the reliability of its findings. The results demonstrate a statistically significant and clinically meaningful increase in cardiovascular mortality risk for diabetic individuals with retinopathy compared to those without. This conclusion has profound implications for clinical practice, suggesting that the identification of DR on a retinal exam should not only trigger ophthalmologic follow-up but also prompt a more aggressive assessment and management of the patient's overall cardiovascular health. The paper solidifies the concept of the retina as a window to systemic vascular health and underscores the interconnectedness of diabetic complications.

III. EXISTING SYSTEM

The existing system is based on the CVDNet framework, which uses the ResNet50 deep convolutional neural network architecture. It predicts cardiovascular disease risk by analyzing retinal fundus images from patients with diabetic retinopathy and hypertensive retinopathy. The system extracts vascular features automatically using deep learning techniques. ResNet50 uses residual connections to improve gradient flow and enable deeper network training. The model processes retinal images through multiple convolutional layers to learn hierarchical features. These features are used to classify patients into different cardiovascular risk categories. The system reduces the need for manual feature extraction. It provides a noninvasive approach for cardiovascular risk prediction. However, ResNet50 has a relatively high number of parameters. It may also have limited feature reuse across layers. The system requires significant computational resources. Training may take longer on large datasets. The model may not fully capture subtle vascular patterns. These limitations indicate the need for a more efficient architecture.

3.1 DISADVANTAGES

- High number of parameters increases computational cost.
- Limited feature reuse using residual connections.
- Longer training time with deep architectures.

IV. PROPOSED SYSTEM

The proposed system introduces a DenseNet121–based deep learning architecture for cardiovascular disease risk prediction from retinal images. DenseNet121 makes feature extraction better by linking each layer to all the other layers in a very connected way. This design promotes feature reuse and improves gradient flow across the network. The model requires fewer parameters compared to ResNet50 while maintaining high accuracy. The system processes retinal

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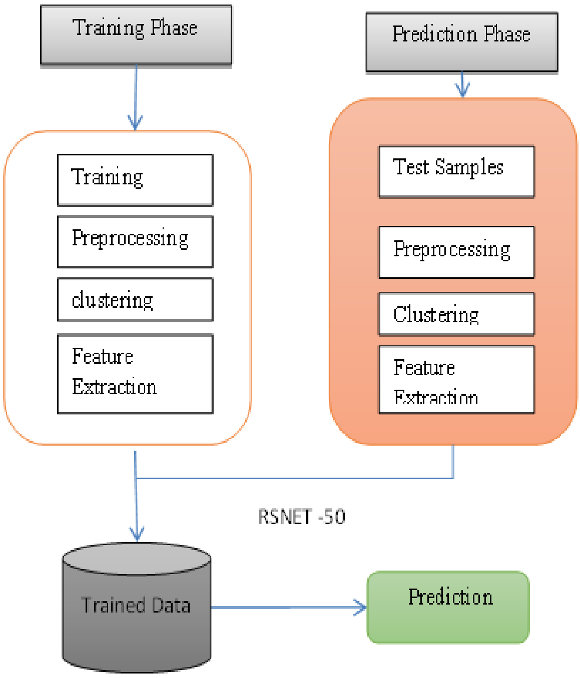
fundus images of DR and HR patients. It automatically extracts vascular features using convolutional layers. Dense connections allow the network to learn both lowlevel and highlevel features effectively. This results in better representation of retinal vascular patterns. The model reduces redundancy and improves learning efficiency. It also minimizes the risk of overfitting on small datasets. The final classification layer predicts the cardiovascular risk level. The proposed system provides a more accurate and computationally efficient solution. It supports early diagnosis and preventive healthcare. The DenseNet121 architecture enhances overall performance compared to the existing system.

4.1 ADVANTAGES

- Better feature reuse through dense connections.
- Fewer parameters with higher accuracy.
- Improved gradient flow and learning efficiency.
- Reduced over fitting on medical datasets.

4.2 ARCHITECTURE DIAGRAM



V. MODULES

- Data Collection Module
- Image Preprocessing Module
- Data Augmentation Module
- Feature Extraction Module (DenseNet121)
- Classification Module
- Prediction and Visualization Module.

5.1 MODULE DESCRIPTION

5.1.1 Data Collection Module

This module collects retinal fundus images from patients with diabetic retinopathy and other high-risk conditions. The images are sourced from medical datasets or hospital records. It ensures that each image is accurately labeled based on cardiovascular risk levels. The module organizes the images into groups for training, validation, and testing. It also identifies and handles missing or corrupted images. Efficient data collection is essential for the model's performance. The module maintains data consistency and quality. The collected images are stored in a clear and organized manner. This module serves as the foundation of the entire system.

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5.1.2 Image Preprocessing Module

This module prepares the retinal images for model processing. It removes noise and enhances image clarity. Images are adjusted to a common size.. Pixel values are normalized to a common scale, which aids in better model learning. The module also improves contrast and eliminates unnecessary background areas. Preprocessing ensures all images have a uniform appearance, which helps in more accurate feature detection. These processed images are then passed to the next stage of the process.

5.1.3 Data Augmentation Module

This module increases the diversity of the training data. It applies techniques such as flipping, rotating, and scaling images. These changes help the model perform well in various scenarios. Augmentation prevents the model from overfitting to the same data. It strengthens the model by simulating different image appearances. The module generates additional training examples, which is especially useful for small medical datasets. This improves model reliability. The new images are added to the training set and used for feature extraction.

5.1.4 Feature Extraction Module

This module uses the DenseNet121 network to extract important features from the images. The network consists of several dense blocks, where each layer receives input from all previous layers. This enhances feature reuse and facilitates smoother learning. The model identifies complex patterns in blood vessels, capturing both basic and advanced features. The network structure reduces unnecessary complexity and speeds up the learning process. The extracted features highlight detailed information about retinal blood vessels. These features are then passed on to the next step for classification.

5.1.5 Classification Module

This module predicts the cardiovascular risk level for each retinal image. It uses fully connected layers after feature extraction. It takes the features from DenseNet121 and applies classification functions to categorize them. The final layer provides the risk level as an output. The model is trained using already labeled data. It employs loss functions and optimization techniques to improve performance. The module adjusts model parameters during training to enhance prediction accuracy over time. The final model is used for testing and evaluating its effectiveness.

5.1.6 Prediction and Visualization Module

This module displays the final prediction results. It classifies each image into a specific risk group. The results are presented to the user or healthcare provider. The module may highlight significant areas of the image to aid in interpretation. It provides clear and easy-to-understand output. It supports informed decision-making and early detection of cardiovascular risk. The results can be retained for future use. It also provides performance metrics for the model. This module completes the entire prediction process.

VI. RESULT AND DISCUSSION

The proposed system uses the **DenseNet121** model to analyze retinal fundus images and predict the risk of cardiovascular disease (CVD). The model was trained and tested using retinal image datasets containing cases of diabetic retinopathy (DR) and hypertensive retinopathy (HR). The performance of the proposed model was compared with the existing **ResNet50** based CVDNet framework.

The experimental results show that the DenseNet121-based model provides improved feature extraction due to its dense connectivity between layers. This allows the network to reuse features effectively and maintain better gradient flow during training. As a result, the model achieves higher prediction accuracy and reduced overfitting compared to the existing system.

The proposed model successfully identifies important retinal vascular patterns such as vessel narrowing, hemorrhages, and other structural abnormalities associated with cardiovascular risk. These features help the system classify patients into different cardiovascular risk categories with higher reliability.

The evaluation results indicate improvements in accuracy, precision, recall, and F1-score when compared with the traditional deep learning model. In addition, the DenseNet121 architecture requires fewer parameters, which reduces computational complexity while maintaining high performance.

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Overall, the results demonstrate that the proposed system provides a more efficient and reliable approach for early cardiovascular disease risk prediction using retinal images. This non-invasive screening method can assist healthcare professionals in early diagnosis, enabling timely treatment and better preventive care for patients.

VII. CONCLUSION

This study proposed a DenseNet121-based deep learning framework for enhanced cardiovascular disease (CVD) risk prediction through the analysis of retinal vasculature in patients with diabetic retinopathy (DR) and hypertensive retinopathy (HR). By leveraging the dense connectivity mechanism inherent to the DenseNet121 architecture, the proposed system effectively addresses the key limitations of the existing ResNet50-based CVDNet model, namely limited feature reuse and high parameter redundancy. The improved gradient flow and feature propagation within the network enable the model to learn more discriminative and complex patterns from retinal fundus images, leading to superior feature extraction and classification performance. The architectural efficiency of DenseNet121 not only reduces the risk of overfitting—a common challenge in medical imaging datasets—but also enhances the overall learning efficiency with fewer parameters. The experimental results demonstrate that the proposed system achieves higher prediction accuracy and reliability compared to traditional deep learning models. By providing a non-invasive, automated, and highly accurate diagnostic tool, this approach holds significant promise for supporting clinicians in early CVD risk assessment, ultimately contributing to more timely interventions and improved patient outcomes in preventive cardiology and ophthalmic screening.

VIII. FUTURE ENHANCEMENT

While the proposed DenseNet121-based system demonstrates improved performance in CVD risk prediction, several avenues for future work can further extend its clinical utility and robustness. First, the model's generalizability can be strengthened by validating it on larger, multi-center, and more diverse datasets encompassing various ethnicities, age groups, and stages of DR and HR. Second, incorporating explainable AI (XAI) techniques, such as Grad-CAM or saliency maps, would enhance model interpretability by visualizing the specific retinal vascular regions contributing to the risk prediction, thereby increasing clinician trust and facilitating clinical adoption.

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