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" Prediction of Cardiovascular Diseases with Retinal Images using Deep Learning"

Prediction of Cardiovascular Diseases with Retinal Images using Deep Learning

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Abstract— Cardiovascular disease (CVD) is the main cause of death globally. The prompt identification and precise diagnosis of CVDs serve as vital for successful treatment and better outcomes for patients. Retinal scanning has evolved as a non-invasive and economical approach for predicting CVD. By harnessing the power of deep learning, specifically Convolutional Neural Networks (CNNs) and MobileNet, this project aims to create an efficient, accurate, and affordable tool for predicting CVDs, ultimately contributing to better patient outcomes and reducing the global burden of these diseases. The suggested model takes use of CNN's ability to autonomously acquire key characteristics from retinal pictures, as well as MobileNet's very light architecture for effective installation. A huge collection of retina pictures, comprising both normal people and patients suffering from heart disease, is used during the training and assessment phases of model. The CNN-type topology is created, using MobileNet as its foundation, adding levels to cater to the unique CVD prediction objective. The system acquires knowledge to correctly classify retina pictures as indicating the presence or absence of CVD after many hours of training and tuning tasks. Functionality is evaluated utilizing common measures like accuracy. The created deep learning framework predicts CVDs using retinal pictures with favourable outcomes, suggesting conceivable advantages for prompt identification, risk evaluation, and economical diagnostics.

Keywords- Retinal images, deep learning, convolutional neural networks (CNNs), MobileNet, cardiovascular diseases (CVDs), early detection, medical imaging, healthcare, risk assessment, non-invasive diagnosis, image classification.

Cardiovascular diseases (CVDs) represent one of the most significant health challenges worldwide, responsible for a substantial portion of global mortality. Early detection and accurate diagnosis are critical to effective intervention and management, offering the potential to reduce the incidence of severe outcomes such as heart attacks and strokes. Despite advancements in medical technology, traditional diagnostic methods for CVDs remain largely invasive, costly, and often inaccessible to large segments of the population, particularly in low-resource settings. This has prompted the exploration of alternative, more accessible diagnostic tools that can deliver early and reliable detection of cardiovascular conditions.

One such promising alternative is retinal imaging, a non-invasive technique that provides a detailed view of the blood vessels in the retina. The retina, being the only part of the human body where blood vessels can be directly observed, offers a unique opportunity to assess the overall health of the cardiovascular system. Changes in the

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retinal microvasculature can reflect broader systemic vascular conditions, including those associated with CVDs. As a result, retinal imaging has emerged as a potential tool for assessing cardiovascular health and predicting related diseases.

The advent of deep learning, particularly Convolutional Neural Networks (CNNs), has further expanded the potential of retinal imaging in the medical field. CNNs exhibit promising outcomes when it comes to the recognition and classification operations of images, rendering them appropriate to analyse more sophisticated medical imaging data. MobileNet, a lightweight CNN architecture, offers the advantages of efficient computation and low memory requirements, making it ideal for deployment in resource-limited settings, like mobile health applications.

- ***Objective Of The Study***

The goal of this research is to create a model powered by deep learning, predicting cardiovascular diseases based on the retina pictures leveraging the MobileNet architectural framework and Convolutional Neural Networks (CNNs). The project aims to harness the non-invasive nature of retinal imaging combined with the powerful feature extraction capabilities of CNNs to create an accurate, efficient, and cost-effective tool for early detection and diagnosis of CVDs. By providing a reliable method for identifying individuals at risk, this project seeks to support healthcare professionals in making timely interventions, ultimately improving patient outcomes and reducing CVD-related mortality.

- ***Scope Of The Study***

The scope of this project encompasses the development and evaluation of a deep learning model for predicting cardiovascular diseases (CVDs) using retinal images. The project involves several key phases: data collection, where a large dataset of retinal images from both healthy individuals and CVD patients is assembled; data preprocessing- augmentation, normalization, and resizing to improvise diversity and quality of image; model development, utilizing Convolutional Neural Networks (CNNs) with MobileNet architecture for efficient feature extraction and classification; and performance evaluation using metrics like accuracy. The final model aims to be deployable in clinical settings, providing a non-invasive, cost-effective tool for early detection and diagnosis of CVDs. Future work may include further validation, integration into healthcare systems, and adaptation for broader applications in medical imaging.

- ***Problem statement***

CVDs is responsible for majority deaths around the globe, with early detection being critical to effective treatment and prevention. However, traditional diagnostic methods are often invasive, expensive, and not universally accessible. The challenge lies in developing a non-invasive, cost-effective, and accurate diagnostic tool that can be easily deployed in diverse clinical settings. This project addresses this issue by leveraging retinal imaging and deep learning techniques to predict CVDs. By developing a model that can analyze retinal images for early signs of CVD, the project aims to improvise prompt recognition, make enhancement to patient results, and cut down expenses incurred for healthcare.

- **Related Work**

[1] proposed a unique technique for detecting CVD that used details gathered from retinal imaging and DXA records. They evaluated a grown-up Qatari population of five hundred individuals from Qatar Biobank (QBB), featuring the same percentages of those with CVD and unaffected groups of people. They conducted a case-control research using a unique multiple-modal approach (which combined data from several modalities—DXA and eye retina pictures) to put forward a deep learning-centric method to differentiate between those with CVD and the unaffected groups of people. The unimodal frameworks using eye retina pictures as well as DXA details obtained

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over seventy per cent of accuracy for each of the inputted image data-type. The multifaceted approach enhanced accuracy by 78.3% when it comes to the classification between those with and without CVDs. They employed a gradient category activating map to emphasize those regions that were relevant in eye retina pictures, exerting the greatest effect on the suggested deep learning-centric model's conclusions.

This seminal paper [2] introduces the concept of Residual Networks (ResNets), a breakthrough in deep learning that addresses the degradation problem in very deep networks. By incorporating residual learning, the authors enable the training of networks with significantly more layers, leading to improvements in image recognition tasks. The research showcases ResNet's superior performance on benchmark datasets and highlights its impact on the development of deeper and more powerful neural networks.

This groundbreaking study [3] demonstrates the potential of deep learning in dermatology by developing a deep neural network that classifies skin cancer with accuracy comparable to dermatologists. The authors trained a CNN on a large dataset of labeled skin lesions and validated its performance on new images. The research highlights the potential of AI in providing accessible and accurate diagnostic tools, especially in areas with limited medical expertise.

[4] presents TensorFlow, an open-source platform for large-scale machine learning. The authors describe the system's architecture, which supports distributed computing and flexible model deployment. TensorFlow's design enables researchers and developers to build, train, and deploy machine learning models efficiently. The paper discusses the system's impact on the machine learning community, emphasizing its role in advancing AI research and application development.

As one of the important aspects in detecting CVD involves monitoring retinal vessels; [5] leveraged the procedures associated with those measures indicate the existence of illness. The primary job of eye retina vessels is to collect data from tissues that is then utilized for the diagnosis and cure of cardiovascular disorders, namely, blood pressure, stroke, glaucoma, and so on. The captured eye retina picture was cleaned subsequently followed by segmentation.

[6] describe the creation and verification of frameworks that use deep learning for automated estimation of retinal-vessel fineness in pictures of eye retina, utilizing various multiethnic multi-country datasets totalling over seventy thousand images. Retinal-vessel fineness measurements by the frameworks and professional human scorers were very consistent, with total intraclass relationship coefficients ranging from 0.82 to 0.95. The algorithms outperformed professional scorers in predicting the relationship amongst retinal-vessel fineness measures and CVD danger indicators such as blood pressure, total cholesterol, BMI, and glycated haemoglobin readings.

[7] look into the application of eye retina pictures, combined with pertinent clinical information about them, for estimating the mass of the left ventricular and volume at the end of diastolic contraction, and then forecast a cardiac arrest. By employing merely, the retinal pictures and demographic info, they trained a multiple-channel variational autoencoder and a deep regressor architecture that could calculate the mass of the left ventricular and volume at the end of diastolic contraction, and then forecast the likelihood of cardiac arrest events in patients.

[8] built a framework built upon the deep learning concept to estimate the age of eye retina using over nineteen thousand fundus pictures taken from over eleven thousand subjects (of interest) with no disease background at entry. Across the remainder of over thirty-five thousand subjects, an eye retina age gap was created by subtracting the anticipated age from the chronological one. Regression techniques were utilized to determine the relationship amongst arterial rigidity measure and eye retina age gap. A combination of Cox proportional hazards regression techniques and limited cubic slopes were implemented to investigate the relationship that exists between incident CVD and eye retina age gap.

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- **Proposed Cardiovascular Disease Prediction System**

The proposed system (subsequently shown in the fig 1 and fig 2) aims to improve cardiovascular disease (CVD) prediction through a deep learning framework using MobileNet architectural framework and CNNs. The MobileNet’s lightweight design ensures efficient processing of large retinal image datasets, while CNNs enhance feature extraction capabilities. The system involves preprocessing retinal images through resizing, normalization, and augmentation to optimize data quality. The MobileNet-based CNN model is trained to classify images based on CVD presence or absence. Performance is evaluated using accuracy and other metrics. This approach offers a scalable, cost-effective tool for early CVD detection, supporting timely interventions and improved patient care.

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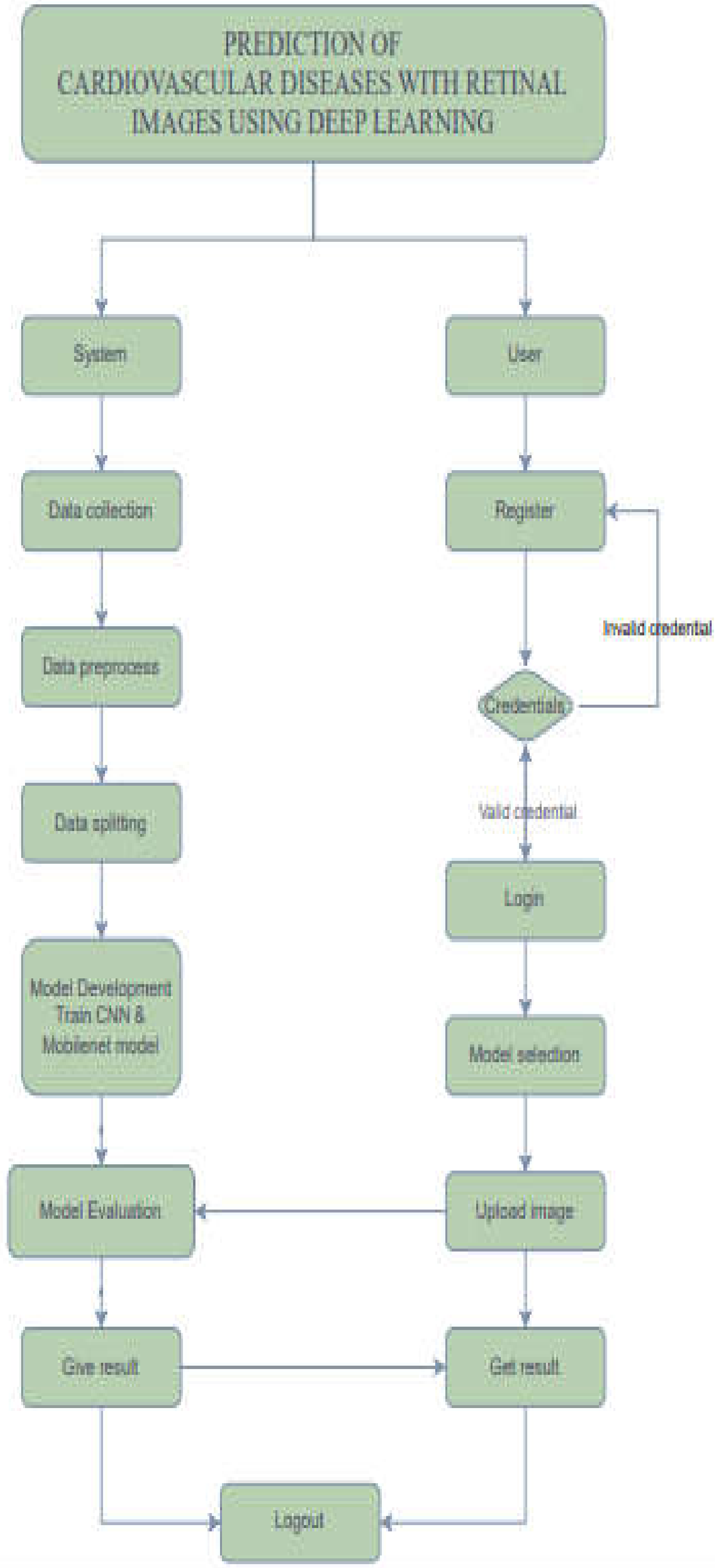

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Fig 1 : *Block Flow chart of cardiovascular disease prediction system*

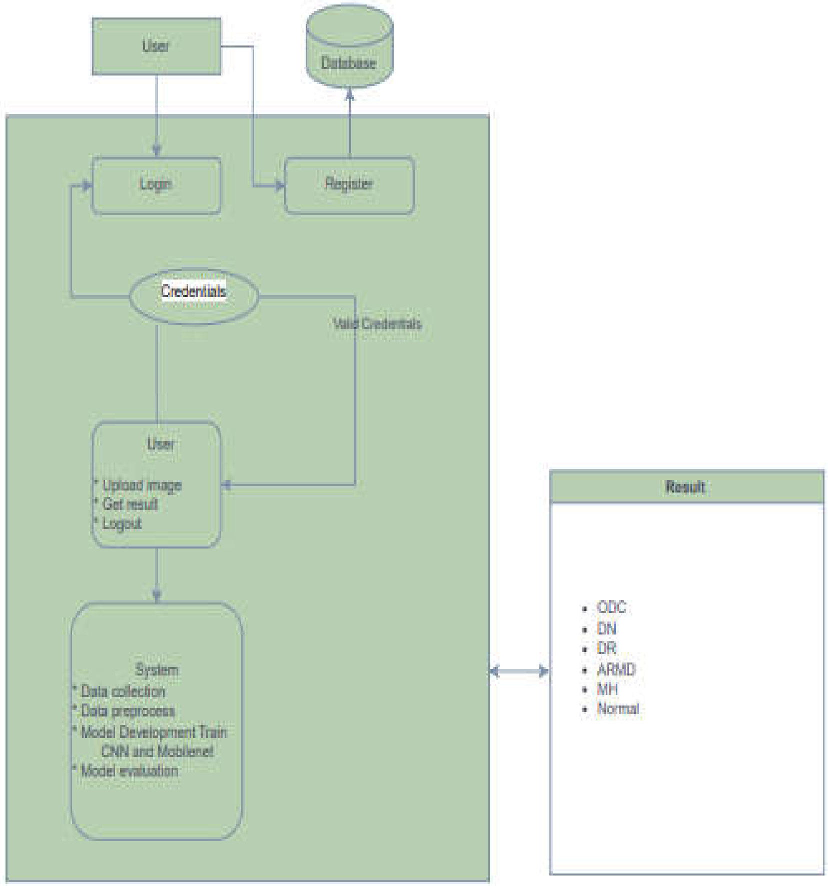

Fig 2 : *System Architecture of cardiovascular disease prediction system*

- ***Methods***

Here, we list the methodologies that we use in this study to predict cardiovascular disease.

- *Convolutional Neural Networks*

For the specific task of CVD prediction based on retinal images, MobileNet architecture is particularly advantageous. MobileNet is designed for efficiency, employing depth-wise separable convolutions to reduce computational complexity and parameter count. This approach involves performing convolutions independently on each channel (depth-wise convolutions) and then combining the respective features through point-wise convolutions, significantly decreasing the model's size and computational demands. Such a lightweight model is well-suited for processing large datasets and deploying in real-time clinical applications, where rapid and accurate analysis of eye retina images is crucial.

CNNs when integrated with the MobileNet architecture, offer a powerful and efficient solution while predicting cardiovascular diseases based on eye retina images. By automating the feature extraction process and handling large volumes of data effectively, these paradigms can enhance diagnostic accuracy and support early detection and intervention, thereby, improve patient outcomes in the realm of cardiac health.

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- ***MobileNet***

MobileNet is a convolutional neural network architecture designed for efficiency and optimized for deployment on mobile and embedded devices. It is particularly effective in real-time applications such as predicting cardiovascular diseases (CVDs) based on eye retina images due to its reduced computational complexity and smaller model size. A key feature of MobileNet is its use of depth-wise distinguishable convolutions, which can comprehensively streamline the convolution process. This approach divides the convolution into two stages: depth-wise convolutions, where a separate filter is applied to each input channel independently, reducing the number of parameters and computations; and point-wise convolutions, where 1x1 convolutions combine these features into a cohesive representation. This distinguishing allows MobileNet to capture detailed image features that possess fewer computations.

Additionally, MobileNet employs the ReLU activation function, with MobileNetV2 using ReLU6 to enhance numerical stability and performance. Incorporation of batch normalization is done to stabilize and expedite the operation of training by being able to normalize the inputs onto every level, thus improving convergence and overall efficiency. MobileNetV2 introduces linear problems in its residual blocks, which streamline the network by removing non-linearity at the end of every block present, thereby reducing computational load without compromising accuracy. The architecture also uses global average pooling in the place of fully connected levels, aggregating feature maps into a single vector and reducing the number of parameters while preventing overfitting.

These architectural preferences make MobileNet highly suitable for processing large volumes of eye-retina image data efficiently. For CVD prediction, this efficiency helps to yield out rapid and accurate analysis, which is critical for real-time clinical applications. MobileNet's compact design and effective feature extraction capabilities ensure reliable performance, facilitating early detection and intervention in cardiovascular health and thus, contributing to better patient outcomes.

- ***Advantages***

Now, we present the advantages of our study, predicting cardiovascular disease:

- **Enhanced Accuracy:** Leveraging deep learning and CNNs, the system automatically extracts and learns complex features from retinal images, leading to more accurate CVD predictions compared to traditional methods.
- **Efficiency and Scalability:** The MobileNet architecture provides a lightweight and computationally efficient model, enabling rapid processing of large datasets and making the system suitable for real-time clinical applications.
- **Non-Invasive and Cost-Effective:** By using retinal images, the system offers a non-invasive diagnostic approach that reduces costs associated with traditional diagnostic procedures, while maintaining high diagnostic accuracy.
- **Adaptability:** The model can be fine-tuned and adapted to various clinical settings and evolving data, enhancing its long-term utility and effectiveness in diverse populations.

- **Modules and its Implementation**

Now, we present the modules along with the corresponding explanation while predicting cardiovascular disease.

- ***System***
  - ***Data Collection***

This module involves gathering a comprehensive dataset of currency images with labeled values, including various denominations and types of notes. The dataset has been partitioned into subsets-namely, training and testing subsets, typically with an 80% to 20% split.

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- ***Data Preprocessing***

This step includes image augmentation, normalization, and resizing for the requirement of enhancement of the quality and variability of the dataset. The preprocessed images are then ready for model training and testing.

- ***Model Training***

Here The CNN models, specifically MobileNet, are trained using 80% of the dataset. This involves fine-tuning model parameters and optimizing performance to accurately predict the value of currency images.

- ***Model Testing***

The remaining 20% of the dataset is used to assess the functionality of the trained models. Computation of metrics such as accuracy, Mean Absolute Error (MAE), recall, and precision to evaluate the model's efficacy in predicting retinal disease values.

- ***Model Saving***

Once trained, the models are saved in a format such as .h5 or .pt to preserve their learned parameters and weights.

- ***Model Prediction***

New retinal images are input into the trained MobileNet model to predict their value. This module handles the prediction process and outputs the estimated value along with a confidence score.

- ***User***

- ***Register***

Users register an account in the system with their credentials to gain access.

- ***Login***

Users log in with their registered credentials to access the currency value detection features.

- ***Upload Data***

Users can upload retinal images for value prediction. These images are processed by the model for analysis.

- ***View Results***

Users receive and view predictions from the model, which indicates the estimated value of the uploaded retinal image along with any confidence scores or additional information.

- ***Logout***

Users can log out of the system to ensure their session and personal data are secure.

- **Discussion and Results**

The results of the proposed cardiovascular diseases prediction system are provided here in the form of implementation screenshots and confusion matrix.

- ***Results***

The confusion matrix for the CNN classifier is signified in the below Fig 13.

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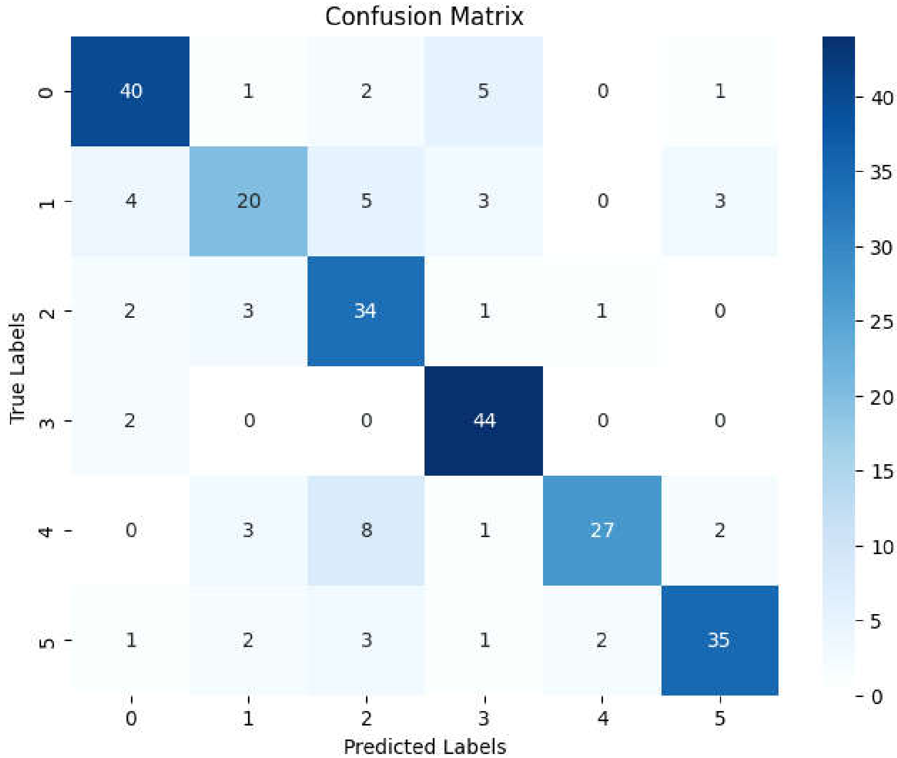

Fig 3 : *Confusion Matrix for CNN*

The confusion matrix for the mobilenet classifier is given in the below Fig 14.

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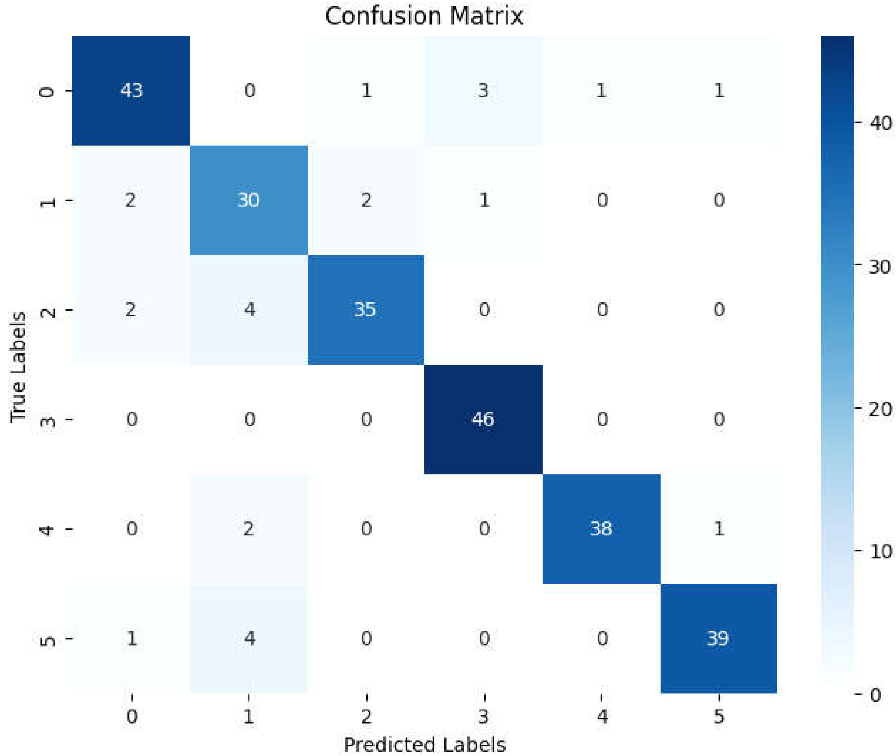

***Fig 4 :** Heatmap of Confusion Matrix for mobilenet*

Here, retinal images were categorized into six groups using two deep learning models, Convolutional Neural Networks (CNN) and MobileNet: ARMD, DN, DR, MH, NORMAL, and ODC. The accuracy of the MobileNet model was 90%, which was a substantial improvement above the 79% accuracy of the CNN model. The classification performance of both of the models is depicted by the confusion matrices in the above Fig 13 and Fig 14.

Specifically, the CNN model misclassified 'DR' as 'NORMAL' and 'MH' as 'ODC' after struggling with several classes. In spite of this, it did a good job of correctly detecting "NORMAL" and "ODC." In contrast, the MobileNet model showed excellent classification accuracy in every class, with 'DR', 'MH', and 'NORMAL' being the most successfully distinguished. When it comes to predicting cardiovascular disorders from retinal pictures, the MobileNet model is a better option because of its greater accuracy, which demonstrates its effectiveness in handling the complexity of retinal image categorization.

- **Conclusion**

This study demonstrates the potential of deep learning models in predicting cardiovascular diseases through the classification of retinal images. The comparative analysis between Convolutional Neural Networks (CNN) and MobileNet revealed that while both models are capable of distinguishing between the six classes (ARMD, DN, DR, MH, NORMAL, and ODC), MobileNet significantly outperforms CNN in terms of accuracy, achieving 90% compared to CNN's 79%.

The higher accuracy and more precise classifications observed with MobileNet suggest that it is better equipped to handle the intricacies of retinal image data, making it a more reliable model for the early detection and prediction of cardiovascular diseases. These findings underscore the importance of choosing the appropriate deep learning architecture for medical image classification tasks, as it can substantially impact the accuracy and reliability of the predictions. Future work could focus on further enhancing the model's performance, exploring additional data augmentation techniques, or integrating more advanced models to improve prediction accuracy even further.

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• Future Enhancement

The current study has demonstrated promising results using deep learning models for the classification of retinal images to predict cardiovascular diseases. However, there are several opportunities for future enhancement. Further optimization of the MobileNet architecture, through hyperparameter tuning and model pruning, could lead to improvements in accuracy and computational efficiency, making it more suitable for real-time applications. Expanding the dataset to include more diverse images from various populations and age groups, as well as employing advanced data augmentation techniques, could enhance the model's generalizability and robustness against variations in image quality.

In addition, exploring ensemble learning techniques by combining multiple deep learning models could yield more reliable and accurate predictions, leveraging the strengths of different architectures. Another critical area for future work is the development of methods to explain and interpret the model's predictions, such as using Grad-CAM or LIME, which would increase trust in the system, especially in clinical settings.

The integration of this model into real-world applications, such as web-based or mobile platforms for clinical use, is a key area for further development, ensuring that the predictions are actionable by healthcare professionals. Longitudinal studies utilizing retinal images over time could provide insights into disease progression, enabling earlier detection and intervention. Lastly, incorporating multi-modal learning by integrating other medical data sources, such as clinical records or genomic data, could further enhance the model's predictive power, offering a more comprehensive assessment of cardiovascular risk. These future enhancements could significantly improve the model's applicability and impact in clinical practice.

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