DAYANANDA SAGAR UNIVERSITY
SCHOOL OF ENGINEERING

DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERING

Major Project Phase-II

CARDIOVASCULAR RISK PREDICTION USING RETINAL IMAGES

Under the Supervision
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Overview

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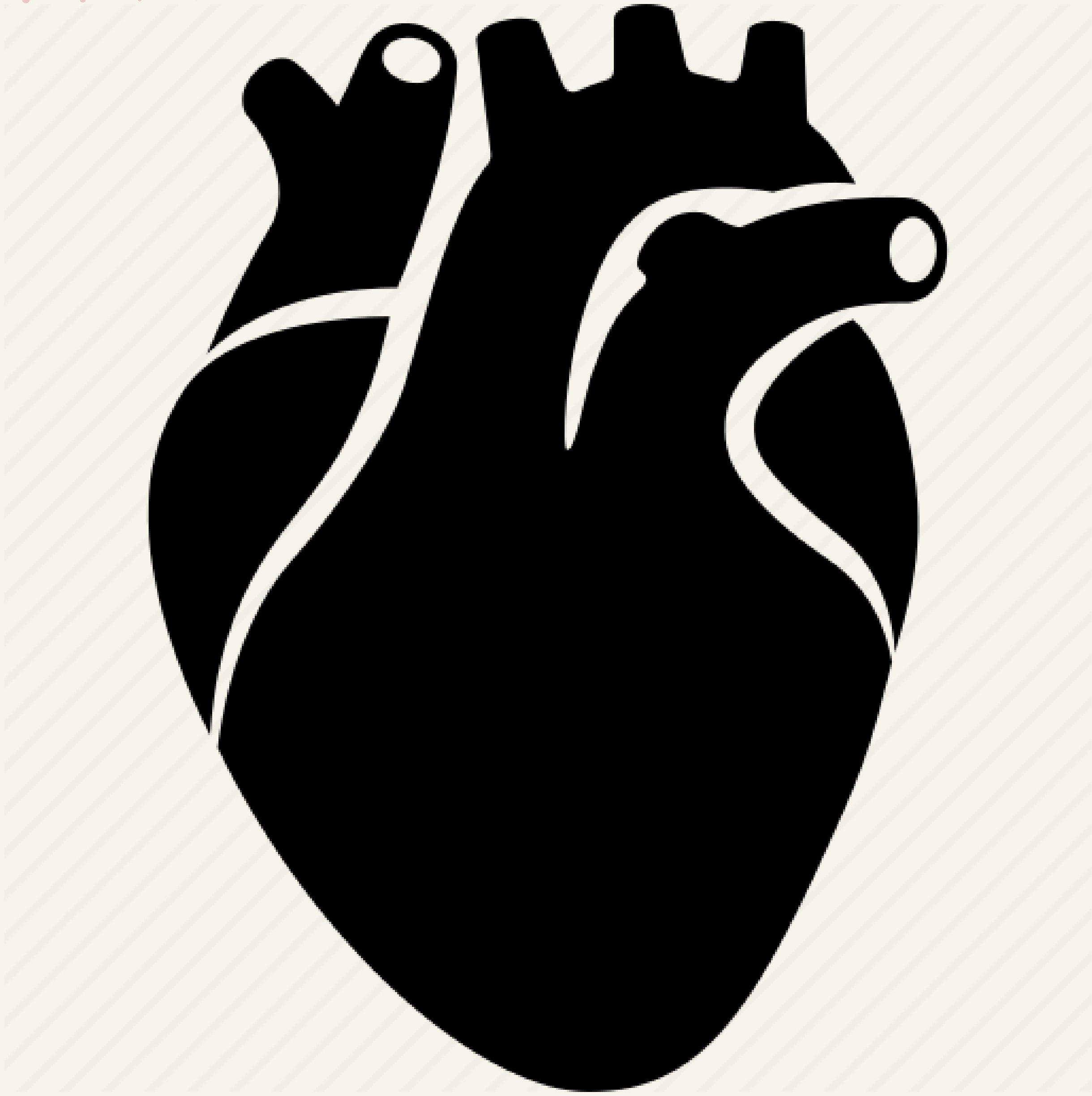
Resources offered by Google can be broadly categorized into physical resources and virtual resources. Physical resources include assets such as hard disk drives (HDDs), computers, etc, and virtual machines (VMs) that come under the category of virtual resources that are ubiquitously present around the globe. These data centers are assigned to a particular region (Asia, North America, South Ameica, etc) and each region is further divided into zones. These zones of a particular region are isolated from each other and are identified by a unique name. These unique names are a combination of the name of the region and the name of the zone. For example, zone c of the East Asia region will be named as Asia-east1-c. This distribution of resources is done for specific reasons. First, redundant data is stored at multiple locations which act as a backup in case of system failure. Second, creating zones reduces the distance between the resources and the clients which reduces communication latency and increases efficiency by fastening the working environment. There are rules to access these distributed resources.

ABSTRACT

- Address the need for early detection of cardiovascular diseases using non-invasive methods.
- Develop a deep learning model to predict cardiovascular diseases from retinal images.
- Collect and preprocess retinal image datasets.Employ deep learning techniques (e.g., CNNs) for analysis.
- Achieve a reliable tool for early cardiovascular disease prediction, enhancing diagnostic accuracy and enabling timely intervention.

INTRODUCTION



Cardiovascular diseases (CVDs) remain a leading cause of morbidity and mortality worldwide. Despite advancements in medical technology, early detection and diagnosis of CVDs often rely on invasive procedures or subjective assessments.This project aims to leverage deep learning techniques to analyze retinal images for predicting cardiovascular diseases. By developing a robust model capable of interpreting complex patterns in retinal images, the goal is to provide an efficient tool for early diagnosis and risk assessment.

Problem Statement

Cardiovascular diseases (CVDs) remain the leading cause of mortality worldwide, emphasizing the critical need for early and accurate risk prediction. Existing CVD risk models primarily rely on clinical factors such as blood pressure, cholesterol levels, and age, often requiring invasive tests that may not be accessible to all populations. Retinal imaging presents a non-invasive alternative for assessing cardiovascular health, yet its potential in predicting CVD risk is not fully realized. The challenge is to develop robust and validated deep learning models capable of analyzing retinal images to predict CVD risk with high accuracy. This research seeks to bridge the gap by creating a reliable, non-invasive CVD prediction tool using retinal images, validated across diverse populations for broader clinical application.

Social/Environmental Impact

- Social Impact: Early detection of cardiovascular risks empowers individuals and communities to adopt preventive measures, reducing mortality and improving overall quality of life.
- Environmental Impact: Minimizing the need for intensive treatments and hospitalizations reduces medical waste and energy consumption, promoting sustainable healthcare practices.

State of the Art-work

Author's Name/ Paper Title	Conference/Journal Name and year	Technology/ Design	Results shared by author	What you infer
Joseph Mellor, Wenhua Jiang, Alan Fleming, Stuart J. McGurnaghan, Can deep learning on retinal images augment known risk factors for cardiovascular disease prediction in diabetes? A prospective cohort study	International Journal of Medical Informatics , April 2023	Deep learning (DL) models using retinal photographs from diabetic retinopathy screening.Poisson regression models to predict cardiovascular disease (CVD) risk in patients with type 1 and type 2 diabetes.ResNet-101 neural network architecture with multiple-instance learning (MIL) for feature extraction.	The DL model provided small but statistically significant improvements in CVD risk prediction compared to baseline models.The C-statistics increased slightly from 0.820 to 0.822 for type 1 diabetes and from 0.709 to 0.711 for type 2 diabetes when DL predictions were added.	The study suggests that further work, such as the use of serial retinal images, may be needed to better integrate retinal data into clinical CVD prediction models

State of the Art-work

Author's Name/ Paper Title	Conference/Journal Name and year	Technology/ Design	Results shared by author	What you infer
Wenyi Hu, Fabian S. L. Yii, Ruiye Chen, Xinyu Zhang, Xianwen Shang, Katerina Kiburg A Systematic Review and Meta-Analysis of Applying Deep Learning in the Prediction of the Risk of Cardiovascular Diseases from Retinal Images	Translational Vision Science & Technology, July 2023	A range of DL models, including Convolutional Neural Networks (CNN) such as ResNet and Inception, were used.Systematic review and meta-analysis of 26 studies using retinal images as inputs for CVD risk prediction.	DL models performed well in predicting risk factors such as *age (MAE 3.19 years), **gender (AUROC 0.96), **diabetes (AUROC 0.80), and **chronic kidney disease (AUROC 0.86)* from retinal images.	The study suggests more work is needed to improve real-world applicability and long-term prediction of CVD.Further standardization and larger, more diverse datasets are needed to validate its clinical utilit

State of the Art-work

Author's Name/ Paper Title	Conference/Journal Name and year	Technology/ Design	Results shared by author	What you infer
Weiyi Zhang, Zhen Tian, Fan Song, Pusheng Xu Enhancing stability in cardiovascular disease risk prediction: A deep learning approach leveraging retinal images	Informatics in Medicine Unlocked, 2023	Deep learning model called Reti-WHO based on the Swin Transformer. It uses retinal fundus images to predict CVD risk scores, aiming to improve stability over traditional methods	Reti-WHO achieved an R2-score of 0.503, Mean Absolute Error (MAE) of 1.58, and a sensitivity of 0.81 in CVD risk prediction. The model was stable over time and more correlated with retinal vascular measurements than the traditional WHO CVD score.	The study suggests that retinal imaging, analyzed using deep learning, could provide a more consistent and non-invasive means of predicting CVD risk, particularly addressing fluctuations seen in traditional risk scores over time.

State of the Art-work

Author’s Name/ Paper Title	Conference/Journal Name and year	Technology/ Design	Results shared by author	What you infer
Abitha Kujalambal, K. Abhirami, Abikayil Aarthi Prediction of Heart Disease Using Retinal Images by Neural Network Algorithm	International Research Journal of Modernization in Engineering Technology and Science 2023.	Neural Network Algorithm based on retinal imaging. Singular Spectrum Analysis (SSA) for data decomposition. Convolutional Neural Network (CNN) model for disease classification.	The proposed CNN model showed better accuracy (80%) compared to *Support Vector Machine (SVM)* (65%) and *Random Forest* (50%). - The *error rate* for the CNN model was also lower (0.4) compared to SVM (0.5) and Random Forest (0.75)	The study demonstrates that retinal imaging combined with neural networks is effective in predicting heart diseases, achieving higher accuracy and lower error rates. The CNN model performed well in comparison to other traditional algorithms, offering significant potential for automated diagnosis systems using retinal data.

State of the Art-work

Author's Name/ Paper Title	Conference/Journal Name and year	Technology/ Design	Results shared by author	What you infer
Yashwin P Prakash, Boora Siri, Dr. J. Jabez Identifying the Abnormalities in Retinal Images Towards the Prediction of Cardiovascular Disease Using Deep Learning	International Conference on Wireless Communications Signal Processing and Networking (WiSPNET),2024	The study employs deep learning models like VGG-16 and ResNet-50 for analyzing retinal images. It utilizes UNET architecture for segmenting retinal blood vessels and calculates the Arteriolar to Venular Diameter Ratio (AVR)* to assess cardiovascular risk.	The *VGG-16 model* achieved *97% accuracy, while **ResNet-50* reached *95.32%*. This higher accuracy of VGG-16, especially in medical image sensitivity, makes it a more reliable choice. The *AVR* was found to be a useful biomarker, with a lower ratio indicating a higher risk of cardiovascular disease.	The combination of advanced deep learning models and segmentation techniques demonstrated high accuracy in predicting cardiovascular risks, suggesting a promising future for non-invasive diagnostic tools

State of the Art-work

Author's Name/ Paper Title	Conference/ Journal Name and year	Technology/ Design	Results shared by author	What you infer
Sameer Shaikh, Mohammad Bazil Mujawar, Ishan Wagh, Divya Surve, Vrushab Zaveri Heart Disease Prediction Using Eye Retinal Images	International Conference on Advances in Science and Technology, 2023	The study uses CNN with the Inception v3 architecture for predicting heart disease through retinal images. Data preprocessing includes resizing images to 299x299 pixels and standardizing them. The model also leverages *transfer learning* techniques for efficient classification	The model achieved a training accuracy of 97% and test accuracy of 96%, demonstrating high proficiency in detecting heart disease through retinal features.The study found significant contributing factors such as age, systolic blood pressure (SBP), and haemoglobin levels for accurate prediction of cardiovascular disease.	The study highlights challenges with data diversity and model interpretability, which need to be addressed for broader clinical applications

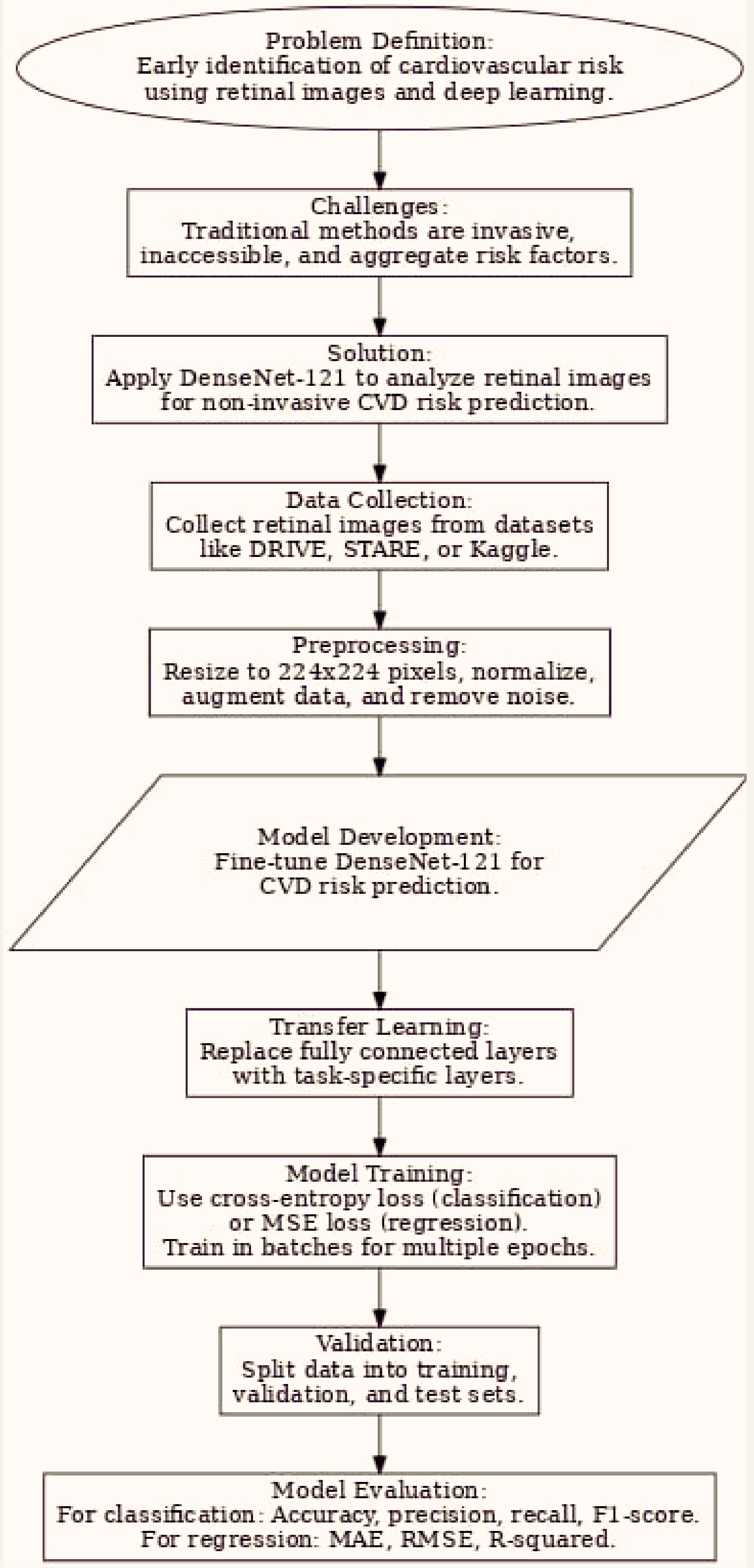
State of the Art-work

Author's Name/ Paper Title	Conference/Journal Name and year	Technology/ Design	Results shared by author	What you infer
Joseph Keunhong Yi et al. Cardiovascular disease risk assessment using a deep-learning-based retinal biomarker: a comparison with existing risk scores	European Heart Journal - Digital Health (2023)	The study uses Reti-CVD, a deep-learning-based retinal biomarker, to predict cardiovascular disease (CVD) risk. Reti-CVD was compared with existing risk scores, such as the Pooled Cohort Equation (PCE), QRISK3, and the modified Framingham Risk Score (FRS).	Reti-CVD was able to identify individuals with intermediate and high CVD risk with a sensitivity of 82.7% (PCE), 82.6% (QRISK3), and 82.1% (modified FRS) across various populations (UK Biobank and SEED).	Reti-CVD offers a efficient method for CVD risk assessment, potentially enabling broader population screening without the need for blood tests. Its strong predictive performance highlights the value of using retinal imaging in conjunction with deep learning to stratify CVD risk.

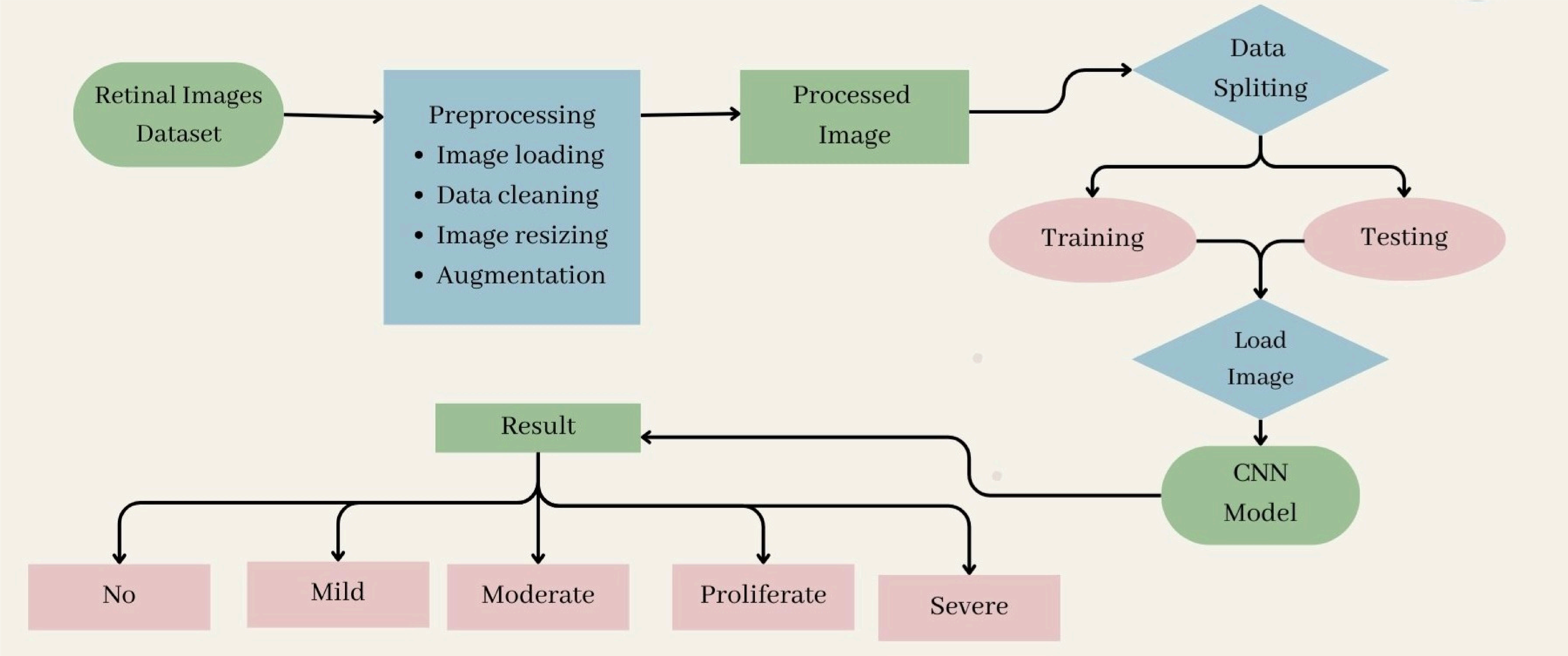
State of the Art-work

Author's Name/ Paper Title	Conference /Journal Name and year	Technology/ Design	Results shared by author	What you infer
Livie Yumeng Li et al. Prediction of Cardiovascular Markers and Diseases Using Retinal Fundus Images and Deep Learning: A Systematic Scoping Review	European Heart Journal - Digital Health (2024)	The most commonly used architecture in these studies is convolutional neural networks (CNNs). Some studies combine deep learning models with clinical risk factors for improved CVD risk prediction.	24 articles were reviewed, most using CNNs to analyze retinal fundus images.38% of studies included clinical risk factors in their prediction models.External validation was performed in only 21% of the studies, indicating a need for more robust validations.	While combining retinal images with traditional clinical risk factors shows promise, there is a need for more external validation and prospective studies to fully understand the clinical impact. Integrating multimodal approaches (images + risk factors) could enhance CVD prediction, but further research is required to assess long-term benefits in clinical settings.

Design


Problem Definition:
Early identification of cardiovascular risk
using retinal images and deep learning.
Challenges:
Traditional methods are invasive,
inaccessible, and aggregate risk factors.
Solution:
Apply DenseNet-121 to analyze retinal images
for non-invasive CVD risk prediction.
Data Collection:
Collect retinal images from datasets
like DRIVE, STARE, or Kaggle.
Preprocessing:
Resize to 224x224 pixels, normalize,
augment data, and remove noise.
Model Development:
Fine-tune DenseNet-121 for
CVD risk prediction.
Transfer Learning:
Replace fully connected layers
with task-specific layers.
Model Training:
Use cross-entropy loss (classification)
or MSE loss (regression).
Train in batches for multiple epochs.
Validation:
Split data into training,
validation, and test sets.
Model Evaluation:
For classification: Accuracy, precision, recall, F1-score.
For regression: MAE, RMSE, R-squared.

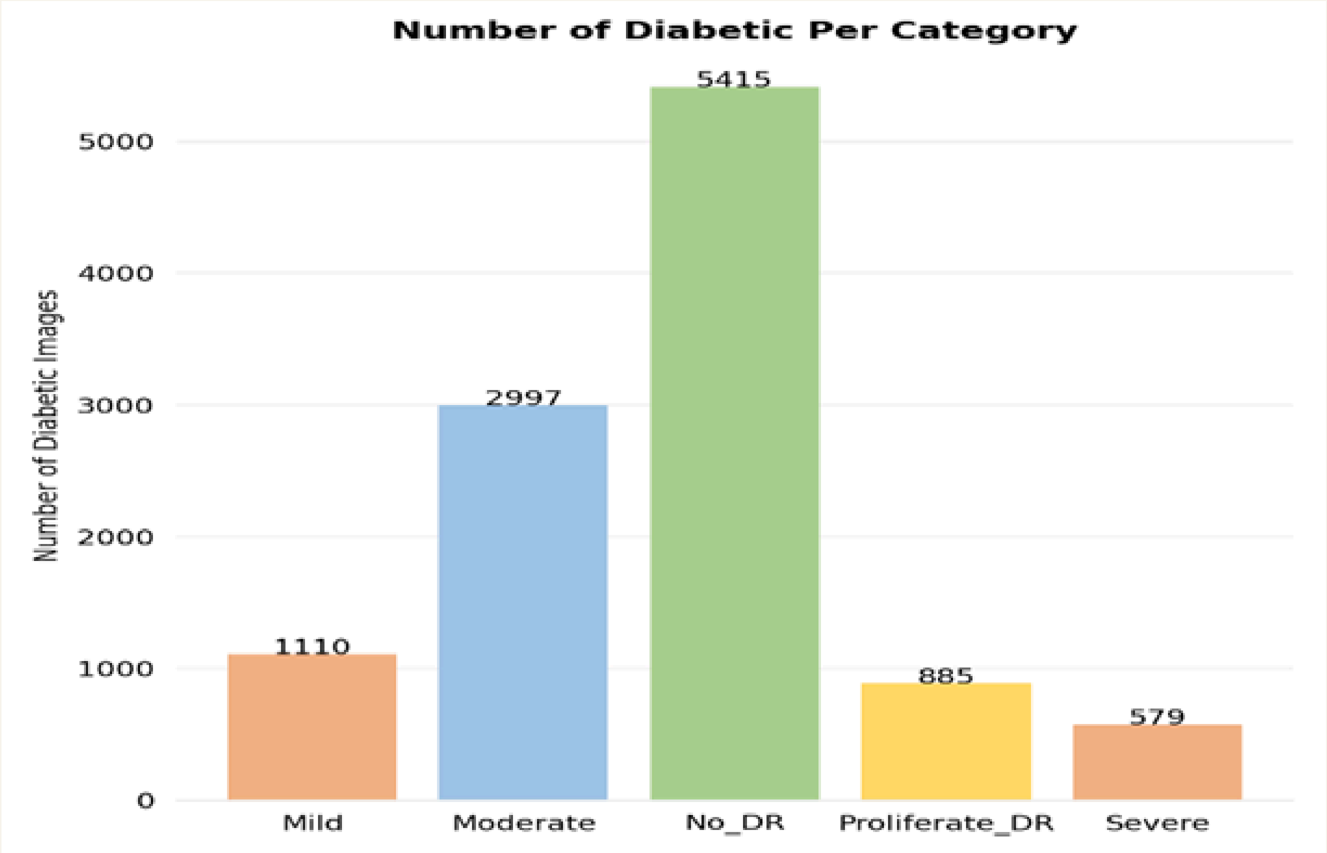
Design-few examples



METHODOLOGY

Data Collection & Preprocessing

- Retinal Image Acquisition: Sourced from Kaggle datasets, and clinical institutions.
- Dataset Labeling: Images graded on a 0-4 scale.
- •0: No.
- •1: Mild.
- •2: Moderate.
- •3: Severe.
- •4: Proliferative.



- Preprocessing:
- Resizing: Standardized to 100 × 100 × 3 .
- Normalization: Scales pixel values to [0,1] for stability.
- Data Augmentation: Rotation, flipping, zooming, contrast adjustments to enhance robustness.

Model Development & Architecture

- Model: DenseNet-121 with a custom classification head.
- Efficient feature reuse, compact size, pretrained on ImageNet.
- Custom Layers:
  - 1024 → 512 → 256 neurons with batch normalization & dropout (0.4).
  - Final 5-neuron softmax layer for classification.

Model Training

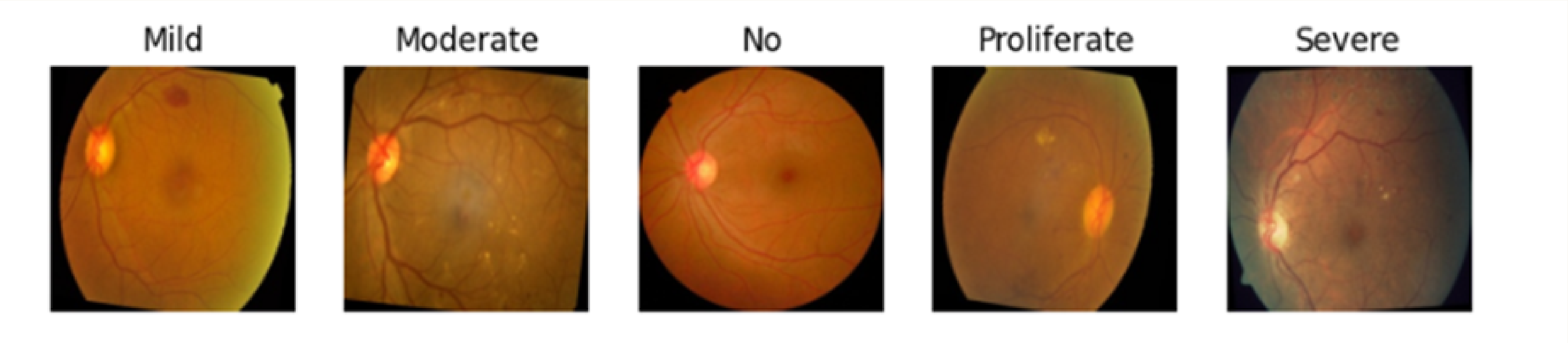
- Loss Function: Categorical Cross-Entropy
- Optimizer: Adam (adaptive learning rate).
- Learning Rate Schedule: Start at 0.001, reduced after 20 epochs.
- Training Setup:
  - Batch Size: 16
  - Epochs: 30
  - Dataset Split: Train, Validation, Test

Model Evaluation

- Confusion Matrix: Analyzes classification accuracy and errors.
- Performance Metrics:
  - Sensitivity : TP / (TP + FN)
  - Specificity: TN / (TN + FP)
  - Precision (PPV): TP / (TP + FP)
  - Negative Predictive Value (NPV): TN / (TN + FN)

IMPLEMENTATION

Sample retinal images



Model Summary

Model: "sequential"

Layer (type)	Output Shape	Param #
densenet121 (Functional)	(None, 3, 3, 1024)	7,037,504
flatten (Flatten)	(None, 9216)	0
batch_normalization (BatchNormalization)	(None, 9216)	36,864
dense (Dense)	(None, 1024)	9,438,208
dropout (Dropout)	(None, 1024)	0
batch_normalization_1 (BatchNormalization)	(None, 1024)	4,096
dense_1 (Dense)	(None, 512)	524,800
dropout_1 (Dropout)	(None, 512)	0
batch_normalization_2 (BatchNormalization)	(None, 512)	2,048
dense_2 (Dense)	(None, 256)	131,328
dense_3 (Dense)	(None, 5)	1,285

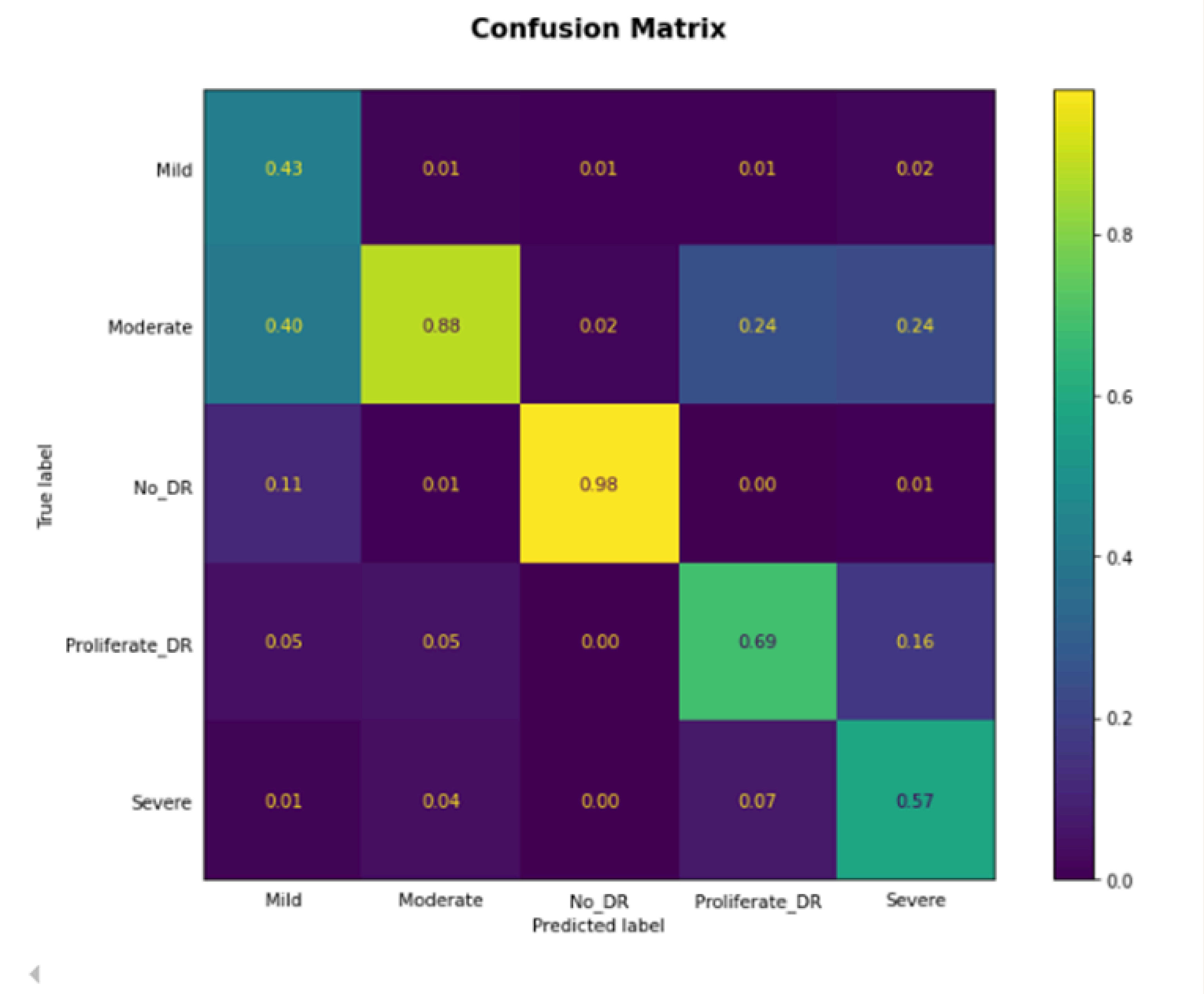
Total params: 17,176,133 (65.52 MB)

Trainable params: 10,117,125 (38.59 MB)

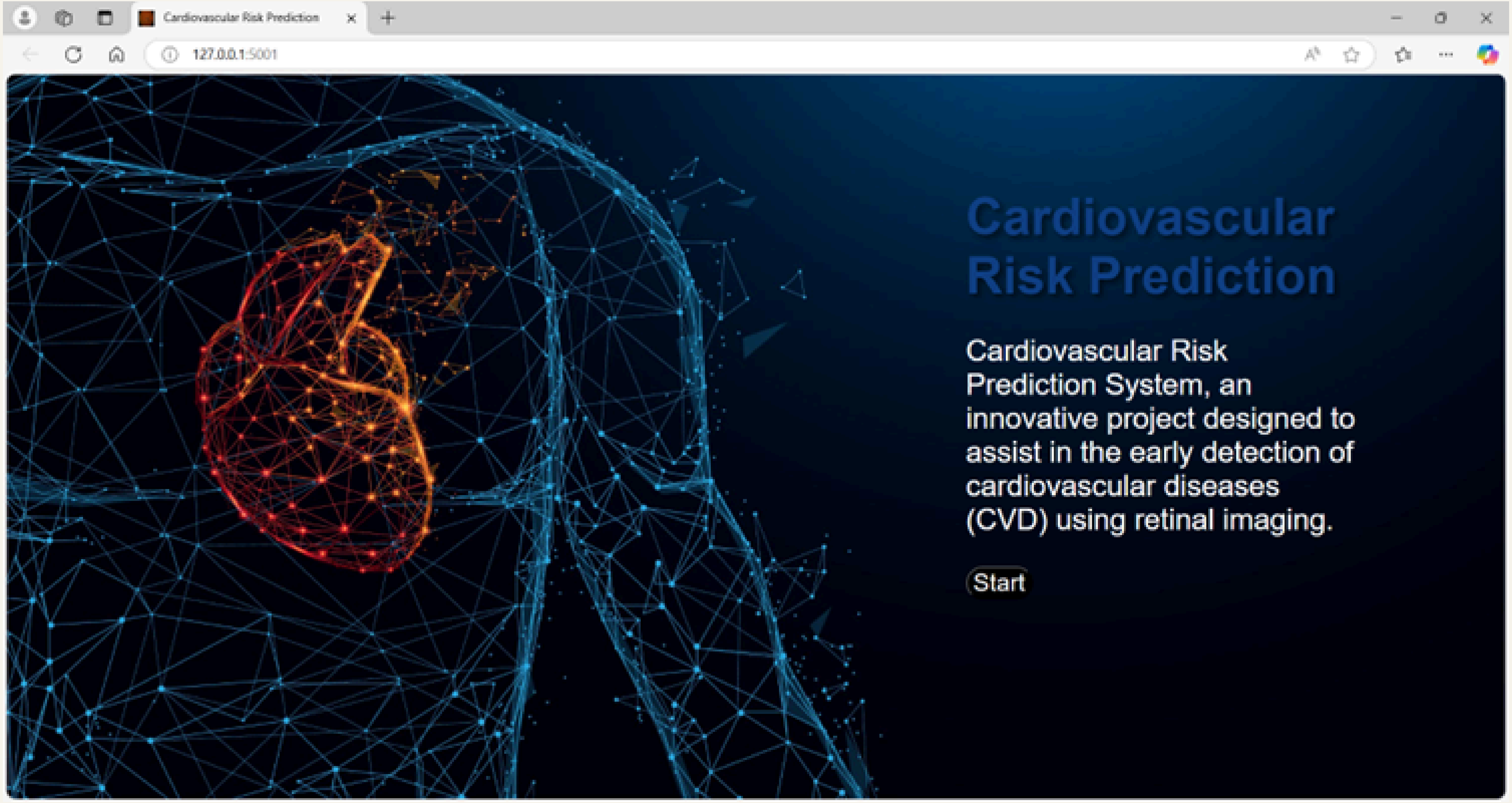
Non-trainable params: 7,059,008 (26.93 MB)

IMPLEMENTATION

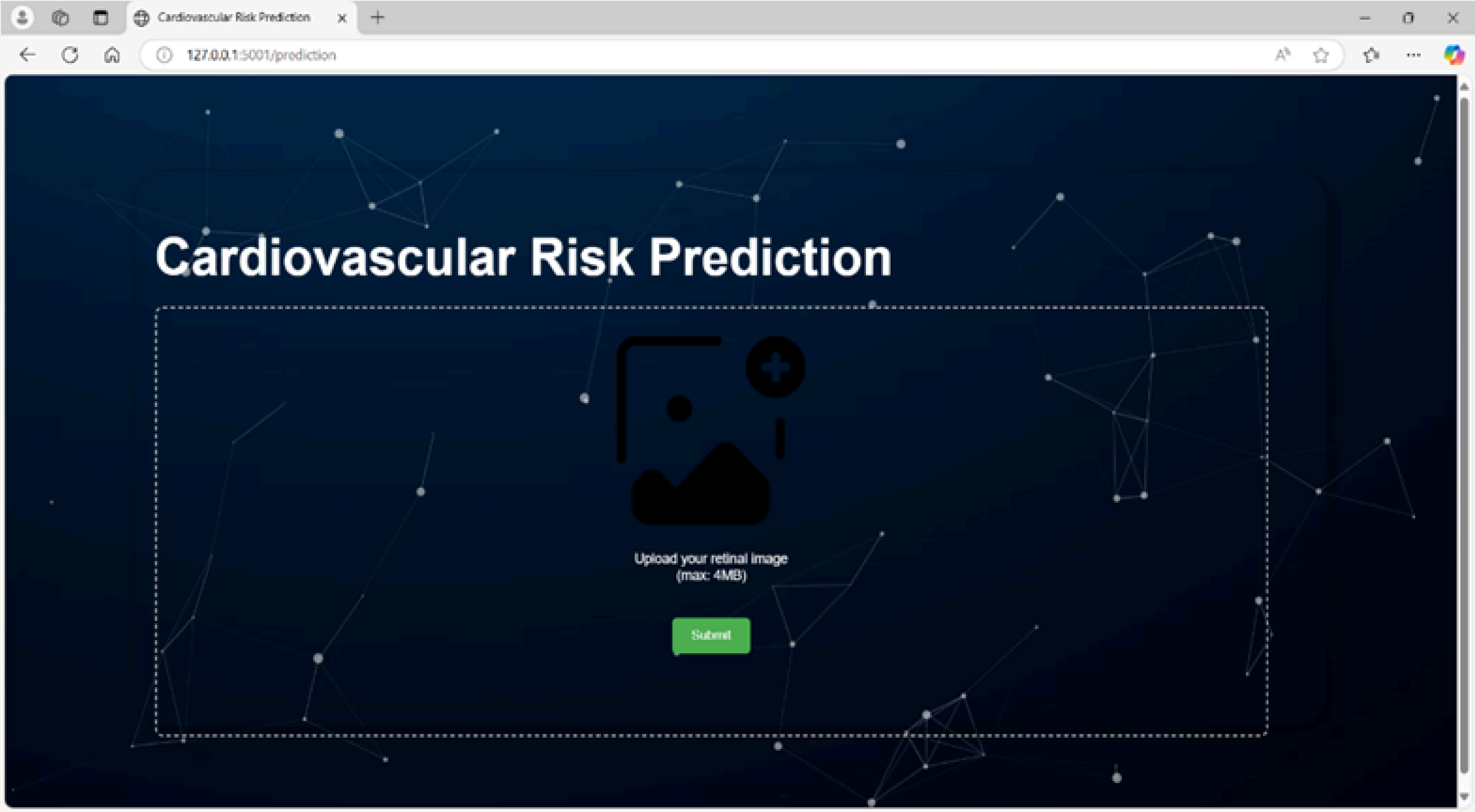
Confusion Matrix



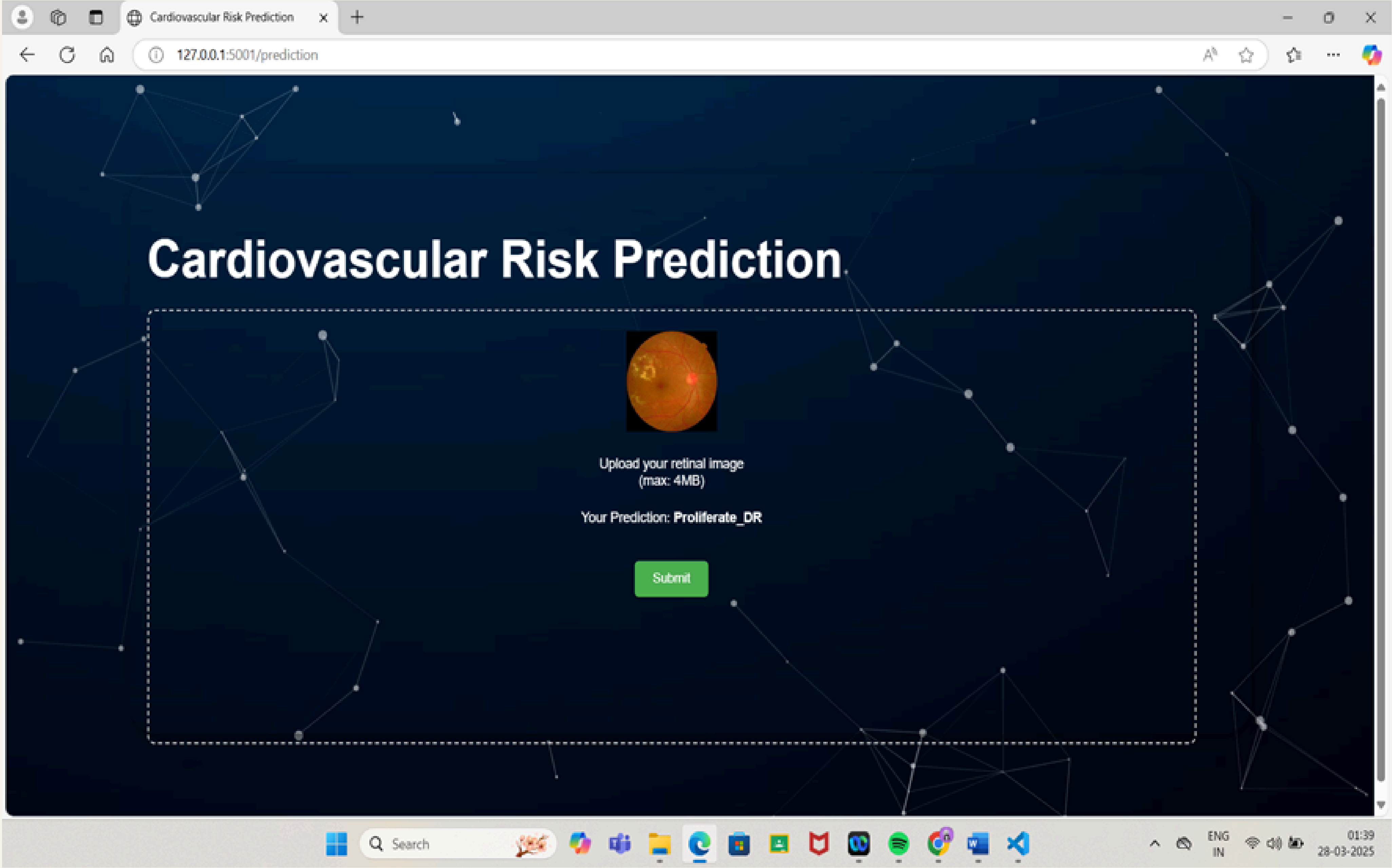
TESTING AND RESULTS



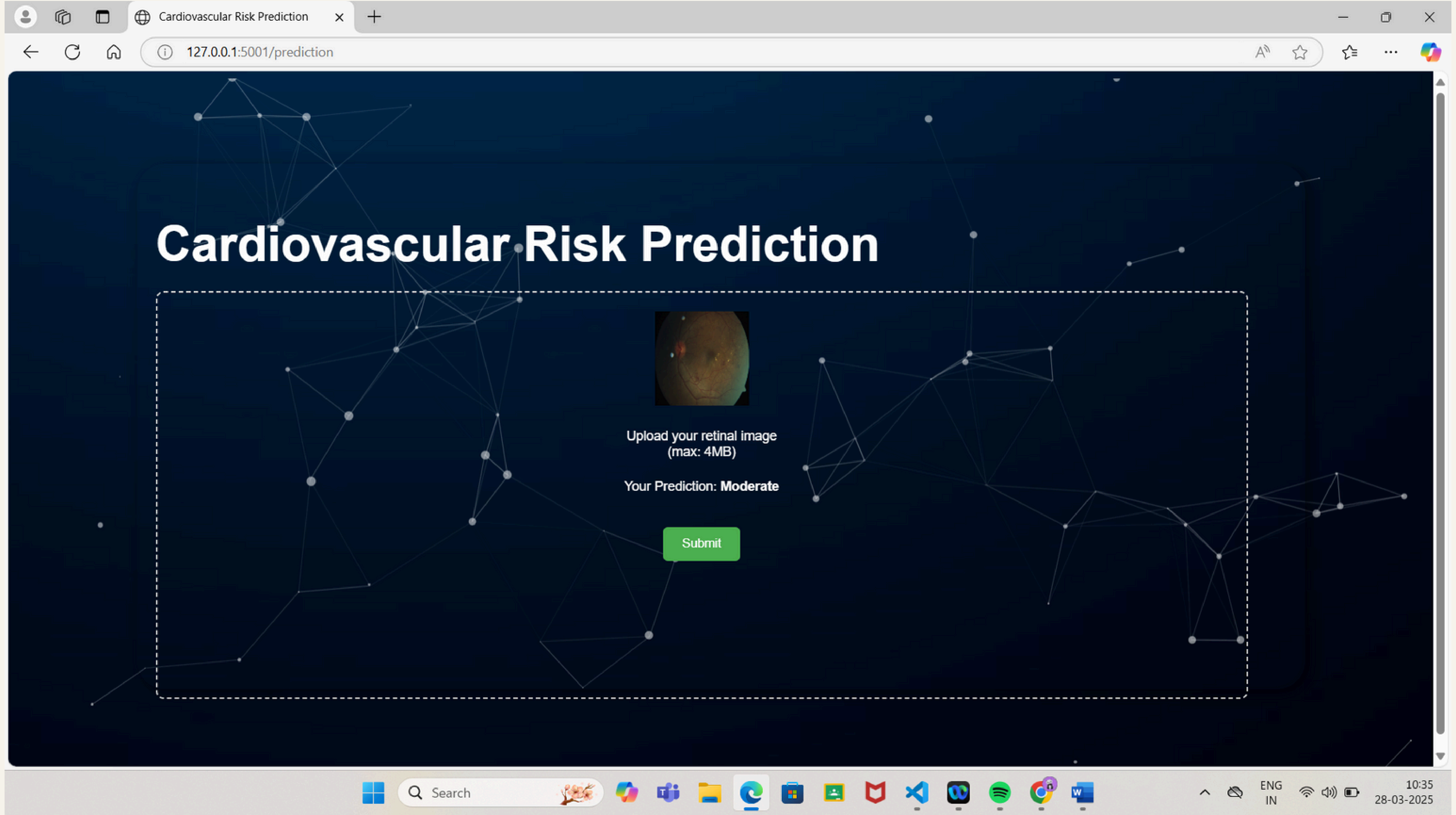
TESTING AND RESULTS



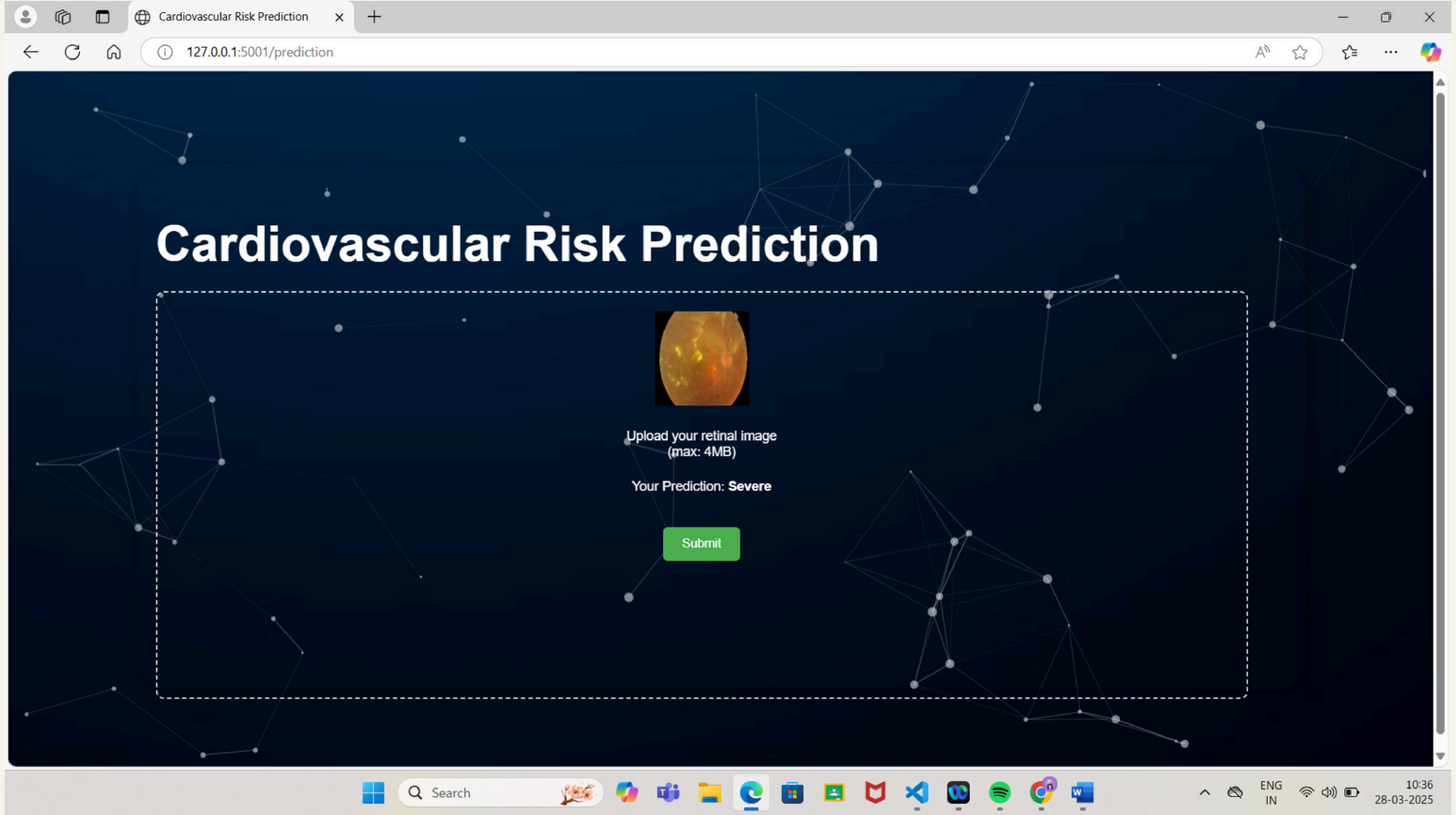
TESTING AND RESULTS



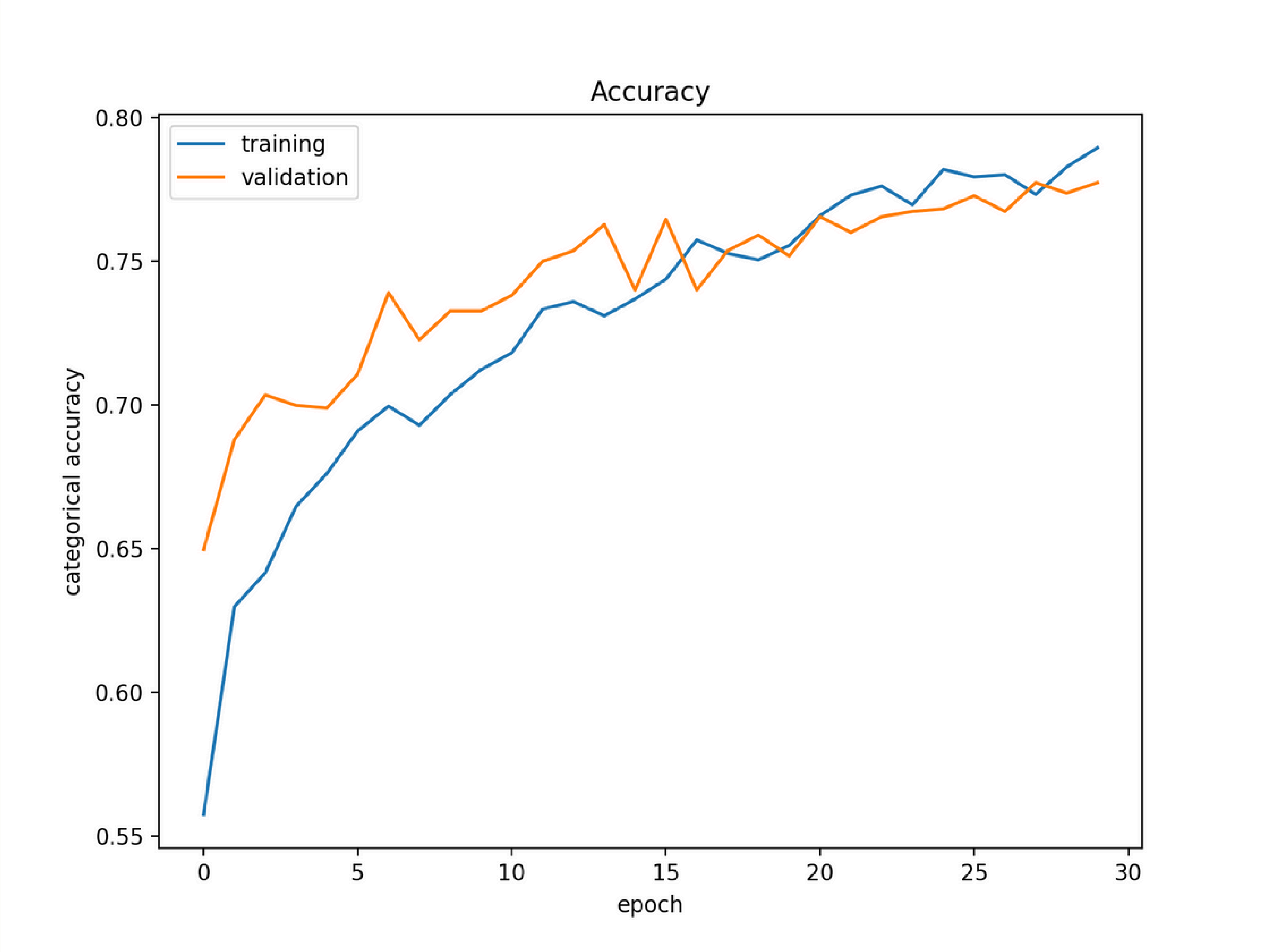
TESTING AND RESULTS



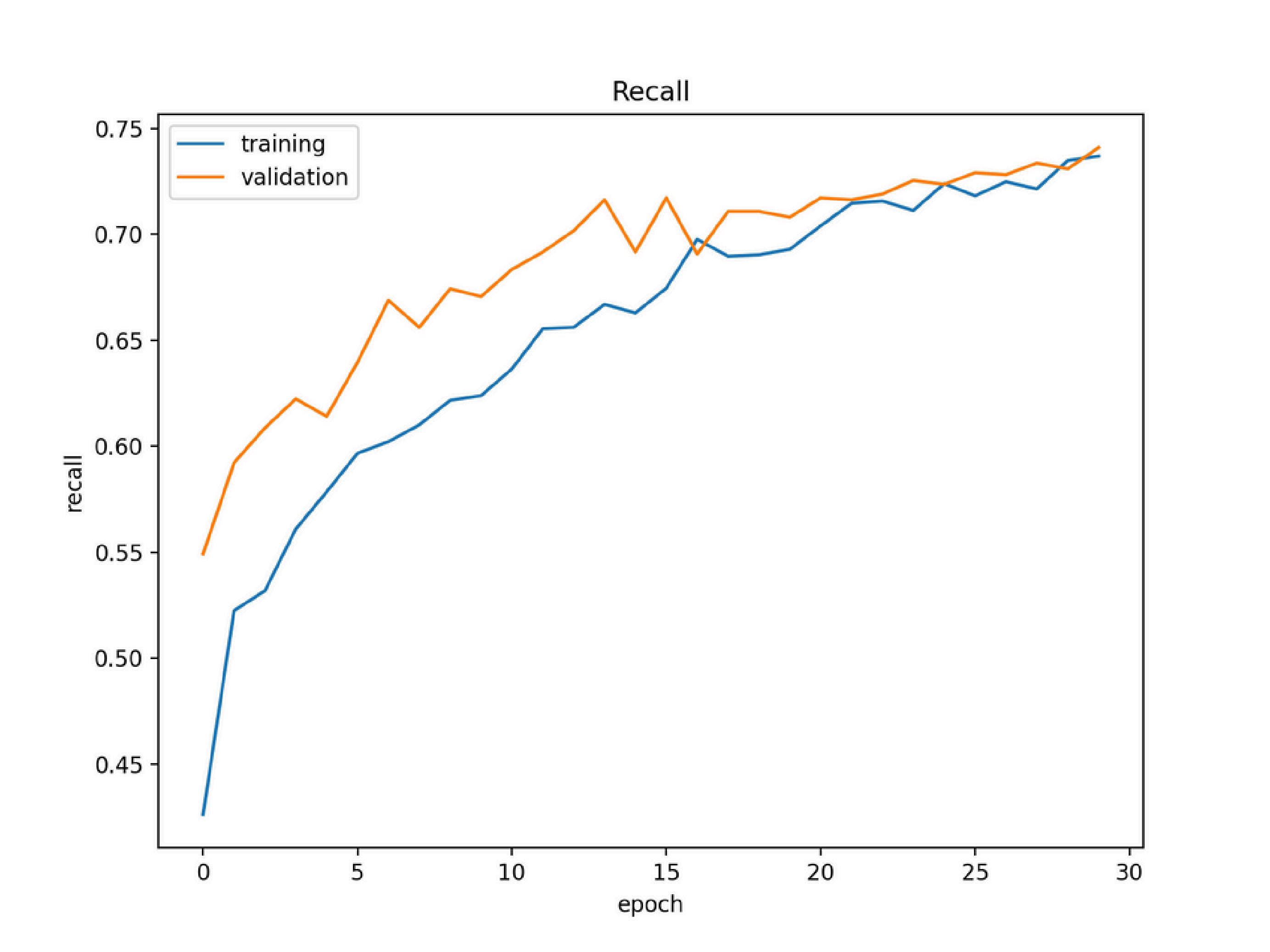
TESTING AND RESULTS

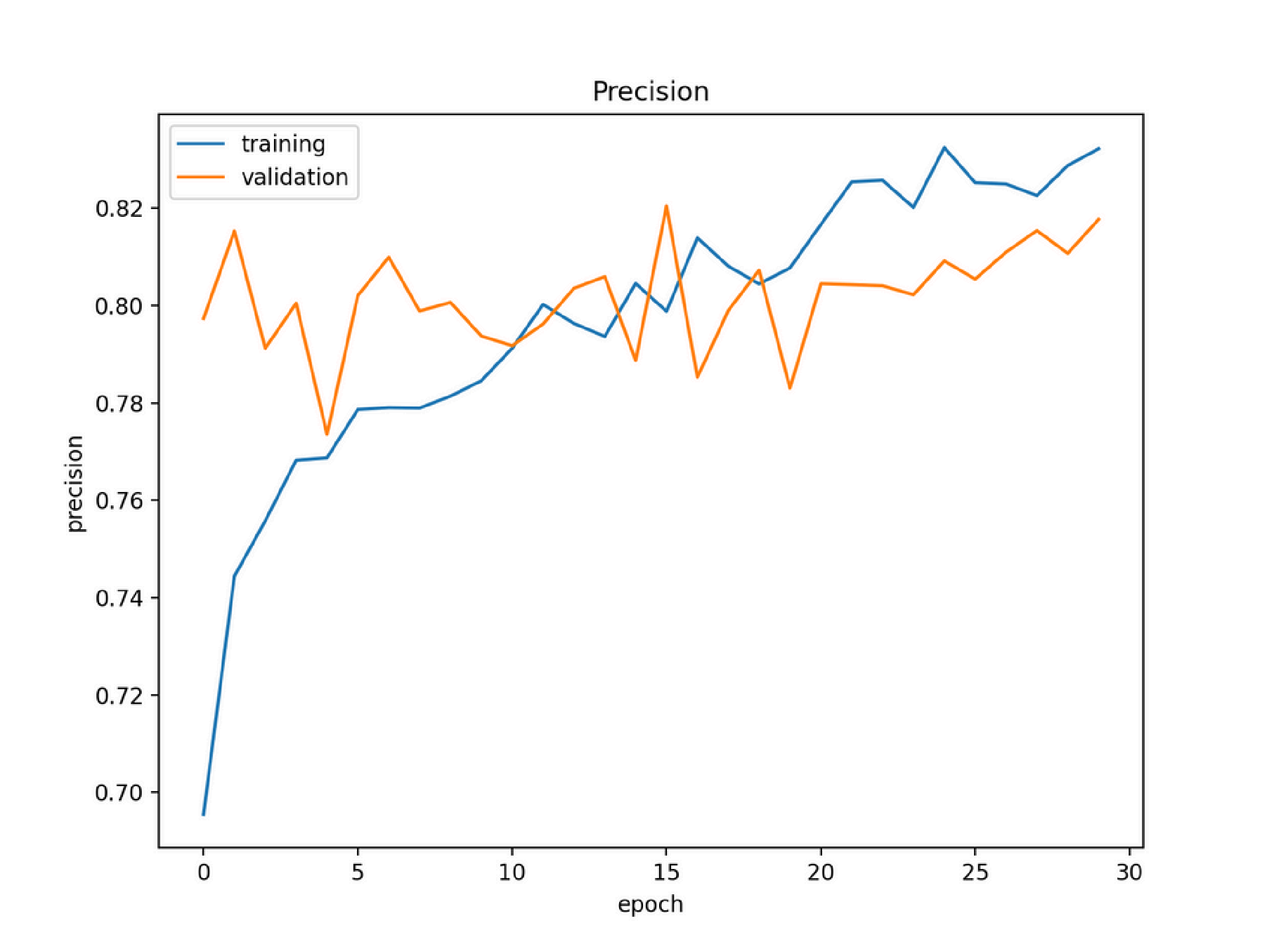


TESTING AND RESULTS



TESTING AND RESULTS





FUNCTIONAL REQUIREMENTS

- Data Input: The system must accept and process retinal eye images in standard formats (e.g., JPEG, PNG).
- Image Processing: It should perform feature extraction to identify and analyze blood vessel patterns and other relevant features in retinal images.
- Risk Prediction: The system must apply machine learning algorithms to predict the risk of a heart attack based on the processed image data.
- User Interface: The application should provide an interface for healthcare professionals to upload images, view risk predictions, and access diagnostic reports.
- Data Storage: The system must securely store images and associated prediction data, ensuring patient confidentiality.

Feasibility Study

- Retinal image datasets are available through various medical repositories, enabling sufficient data for training deep learning models.
- Popular frameworks like TensorFlow and PyTorch provide a reliable platform for implementing deep learning models, making the project technically feasible.
- Initial costs will involve dataset acquisition, model development, and computing resources. These can be managed with open-source tools and cloud-based solutions for cost-effective deployment.
- Hospitals, clinics, and telemedicine platforms are likely to adopt this technology for its accuracy, ease of use, and ability to facilitate early disease detection.

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THANK YOU

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