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RCNN - Based Plaque Detection in Coronary Artery Imaging

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Abstract: *Coronary heart disease (CHD) remains one of the leading health issues worldwide, primarily caused by plaque development that leads to narrowing of coronary arteries. Early identification of such conditions is crucial. Coronary computed tomography angiography (CCTA) is a common diagnostic tool for assessing coronary artery conditions. CCTA requires manual interpretation by a radiologist. We developed a web-based interface in which doctors or patients can upload their CCTA images and get the results. This paper presents an AI-based system that enhances CCTA image analysis through a Recurrent Convolutional Neural Network (RCNN). The proposed system automatically identifies plaque presence within coronary arteries and determines the degree of stenosis. The system achieves 91% accuracy.*

Keywords: *Coronary Heart Disease (CHD), Coronary CT Angiography (CCTA), Plaque, Stenosis, Recurrent Convolutional Neural Networks (RCNN)*

I. INTRODUCTION

1.1 Background

Coronary Heart Disease (CHD) ranks among the leading causes of deaths globally. Early detection is essential to prevent critical events like heart attacks. Early detection can prevent medical emergencies, surgeries and prolong patient life. CCTA has emerged as a valuable non-invasive imaging modality for visualizing coronary arteries and detecting plaque and stenosis. The conventional analysis of CCTA is done by radiologists manually and is therefore subject to bias and variability. Recent advances in artificial intelligence, particularly deep learning architectures such as Convolutional Neural Networks (CNNs) and Recurrent Convolutional Neural Networks (RCNNs), have been used for image classification today. These models automatically perform feature extraction and give high accuracy. These algorithms have demonstrated remarkable potential in medical image analysis. Many proposed algorithms detect whether plague is present or not without giving the level at which the plaque is present to enable the doctors to plan the treatment.

1.2 Problem Statement

CCTA is widely used for diagnosing coronary artery disease, yet existing analysis approaches have significant limitations: Manual Interpretation Challenges: The images produced from the test has to be interpreted by a Radiologist and many be subjected to human error.
Image Quality Issues: Poor contrast images will reduce diagnostic accuracy

1.3 Existing Systems

Traditional CCTA analysis methods depend on manual interpretation and conventional image processing techniques. Clinicians manually review CT images to detect plaques and assess arterial narrowing. This method, although common in current clinical practice, is labor-intensive and greatly depends on the expertise of the clinician. The drawbacks include labor-intensive manual interpretation subjected to errors, quality of image obtained is not very good.

1.4 Proposed System

The proposed system enhances coronary artery plaque detection and stenosis prediction using deep learning techniques, namely Recurrent Convolutional Neural Network (RCNN) architecture.

The system processes input CCTA images through preprocessing, then analyzes them using the trained RCNN model. This approach eliminates the drawbacks of the existing system and provides high accuracy.

1.5 Objectives

- Design and develop a web-based application for CCTA image where the user or doctor can upload and get the plaque and stenosis detected.
- Develop an RCNN-based machine learning model for plaque detection and classification in CCTA images

1.6 Methodology

The methodology followed in the paper is as follows

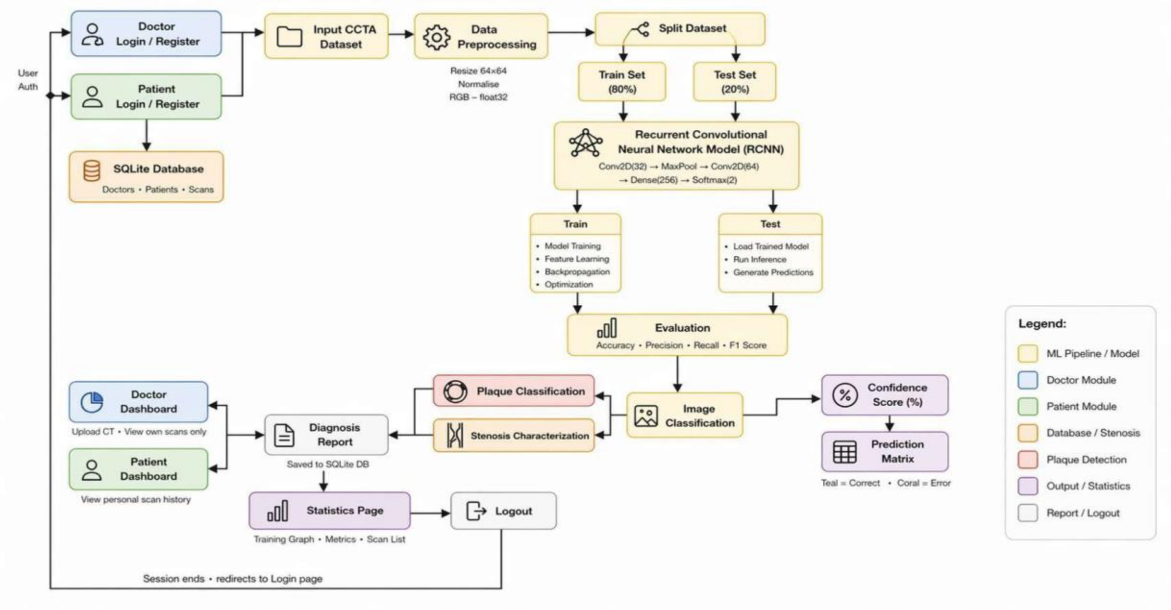

Fig 1: System Architecture for Enhanced Coronary CT Angiography

Compilation of labeled CCTA images from Kaggle (Input CCTA dataset), in preprocessing we resize the images to 64 X 64 images. We split the data into training and testing sets in the ratio of 80:20. Then we give these input images to train the RCNN model. Then we evaluate it for performance.

II.LITERATURE SURVEY

Litjens et al. [2] provided survey on deep learning in medical image analysis. It covers deep CNN architectures, unsupervised models for classification, detection and segmentation.

Shen et al. [5] review paper discussed deep learning applications in healthcare imaging, describing AI's impact on diagnosis and listing existing challenges and limitations.

Cortes and Vapnik [1] applied Support Vector Machines (SVM) and Random Forest for coronary artery disease classification using handcrafted features. This method provides good accuracy but depends heavily on feature extraction expertis.

Jukema et al. [3] discussed AI-based automated coronary plaque quantification using CCTA. This work provids increased precision and reduced human intervention. This techniques identify plaque but did not identify stenosis. Mao et al. [6] presented automatic diagnosis of coronary artery stenosis using deep learning on X-ray coronary angiography butdid not identify plaque. Rajpurkar et al. [4] developed CheXNet, which works on chest X-rays. The literature review reveals significant progress in AI and deep learning for CCTA analysis using CNN, RNN, and hybrid approaches. However, most existing systems address either plaque detection or stenosis assessment, but not both. Our model tries to address both plaque and stenosis.

III.SYSTEM ARCHITECTURE

3.1 System Architecture Overview

As shown in Figure 1, the user and doctors both authenticate themselves. Doctors upload the patient's scans and get the results. Patients have access to their scans and the results. Following evaluation, the system classifies images for plaque presence. When plaque is detected, stenosis characterization estimates its severity. Dashboard displays confidence scores and prediction matrices. SQLite database stores the user's credentials, patient details and scan information.

3.2 Module Descriptions

The system have various modules like user authentication module- which authenticates the users, Data input module – which handles the uploaded scans from the users. Data processing modules for data preprocessing, data splitting, and training. Image classification module for classification of uploaded images. Output module for output generation and results.

IV.IMPLEMENTATION

4.1 Tools and Technologies

The system implementation utilizes:

Component	Technology
Programming Language	Python
Deep Learning Framework	TensorFlow, Keras

Image Processing	OpenCV
Numerical Computing	NumPy
Web Framework	Flask
Frontend	HTML, CSS, JavaScript
Database	SQLite
Visualization	Matplotlib, Seaborn

4.2 Database Schema Design
The SQLite database schema comprises four main tables:
Doctor Table: Doctor ID, name, email, password, specialization Patient Table: Patient ID, name, age, gender, email, password Scan Table: Scan ID, patient ID, doctor ID, image path, upload date, status Report Table: Report ID, scan ID, plaque detection status, stenosis percentage, severity, confidence score

V.RESULTS AND DISCUSSION

5.1 System Interface Results

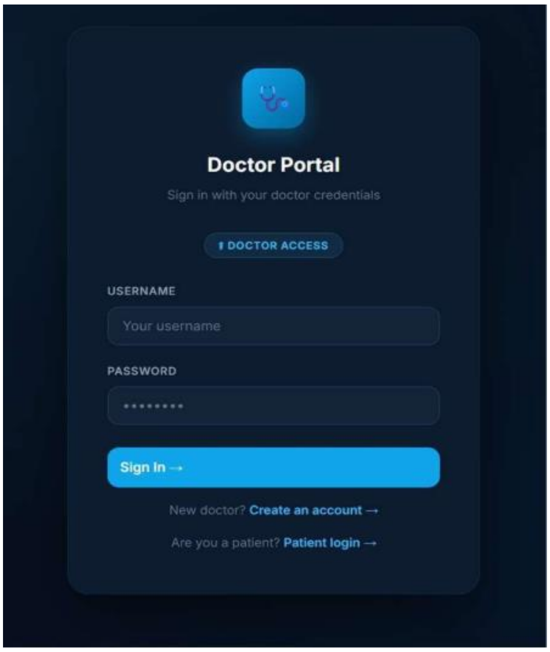

Figure 2: Login portal

Login Portal: The homepage shown in Fig 2 provides an interface for doctors and patients for login.
Doctor Dashboard: Shown in Fig 3 provides a summary of patient numbers, name, scans uploaded, and plaque detection counts.

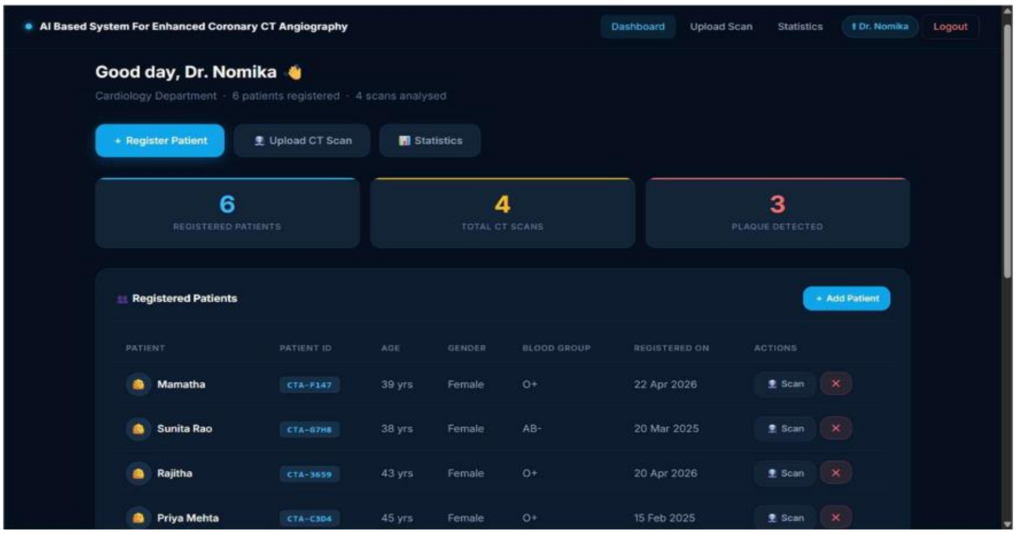

Figure 3: Doctor Dashboard

Patient Registration: The patient has to enter name, age, gender etc and get registered.
Scan Upload: Enables physician selection of patients followed by CT scan upload through drag-and-drop or browse options, with "Analyze & Save" functionality.
Result Display: AI analysis displays plaque presence and stenosis severity with 96.4% confidence, accompanied by suggestions.

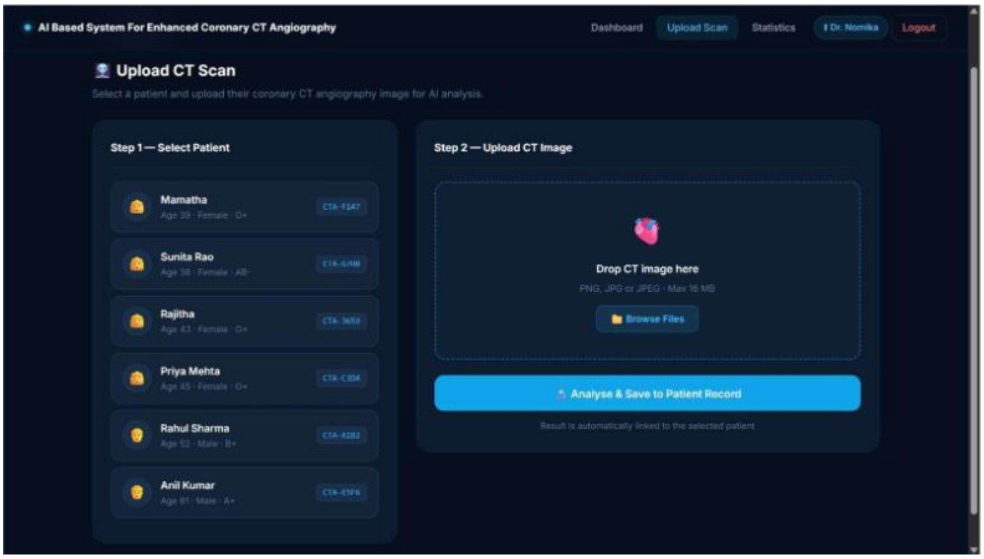

Figure 4: Upload CT scan

Patient Dashboard: Displays patient-specific medical scan data including demographics, scan statistics (total scans, plaque-positive, normal results), and detailed CT scan history with thumbnails, scan IDs, diagnosis, stenosis information, physician details, dates, and accuracy percentages.

Metric	Value
Response Time	2-3 seconds per image
Accuracy	91%
Precision	89%
Recall	92%
F1-Score	90%
Data Consistency	100%
System Reliability	95%

Table 2: Performance Measures

Feature	Existing Systems	Proposed System
Analysis Method	Manual interpretation	AI-based automated analysis
Processing Time	30-60 minutes	2-3 seconds
Accuracy	Variable, experience-dependent	91% accuracy
Stenosis Detection	Limited or absent	Comprehensive severity assessment
User Access	Limited	Separate doctor/patient interfaces
Data Storage	Basic	Structured database with integrity

Table 3: Comparative Analysis

The proposed system demonstrates significant advantages:
- Automated interpretation reducing analysis time from 30-60 minutes to 2-3 seconds
- Consistent 91% accuracy.
- Efficient structured database storage for patient records, scans, and reports

VI.CONCLUSION

6.1 Conclusion

We have developed a web-based system which is user friendly for the analysis of CCTA images, and we were able to detect plaque and stenosis. The web interface connects with the AI model to analyse the images and gives quantitative characterization of stenosis rather than the percentage. This proves valuable in distinguishing cases with clinically significant stenosis above the 50% threshold. The web-based platform enhances application effectiveness through user-friendly interfaces. The system supports the physician in detection and diagnosis.

6.2 Scope for Future Enhancements

We can use 3D CNN and vision transformer models for better accuracy. We can use explainable AI techniques so that we can give good explanations to the prediction given by the model so there will be guiding for the healthcare professionals.

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