

FUSION OF RETINAL IMAGING AND CARDIO VASCULAR SIGNALS USING DEEP LEARNING FOR HEART ATTACK RISK ASSESSMENT

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Abstract - Healthcare systems are increasingly integrating artificial intelligence (AI) and machine learning (ML) techniques to improve early disease detection, risk prediction, and patient management. Traditional approaches for diagnosing diabetic retinopathy (DR) and assessing cardiovascular risks remain largely manual, time-consuming, and prone to inaccuracies, particularly in resource-limited regions. This project proposes a smart healthcare platform developed using Django, which integrates secure user registration with admin-controlled activation, role-based access, and OTP-enabled password recovery to ensure data privacy. The system employs a pre-trained Efficient Net deep learning model for automated classification of DR severity from retinal images, thereby reducing reliance on manual interpretation. Furthermore, a fusion-based machine learning model (XG Boost) is implemented to predict heart attack risk by combining DR indicators with clinical parameters such as blood pressure, cholesterol, heart rate, and ECG scores. The proposed system not only provides risk classification into high, medium, or low categories but also generates probability scores to enhance personalized healthcare recommendations. By unifying deep learning image analysis with structured clinical data in a web-based application, the system enables early diagnosis, preventive care, and improved clinical decision-making. This integration demonstrates the potential of AI-driven healthcare solutions in enhancing accessibility, accuracy, and scalability in modern medical practice.

Key Words: Retinal Imaging, Cardiovascular Signals, Deep Learning, Multimodal Data Fusion, Heart Attack Risk Assessment, Cardiovascular Disease Prediction, Convolutional Neural Networks.

1. INTRODUCTION

In recent years, the integration of artificial intelligence (AI) and machine learning (ML) into healthcare has gained significant attention due to their potential to improve disease diagnosis, risk assessment, and patient care. Chronic diseases such as diabetic retinopathy (DR) and cardiovascular disorders remain among the leading causes of blindness and mortality worldwide. According to the World Health Organization (WHO), diabetic retinopathy affects nearly one-third of diabetic patients, while cardiovascular diseases account for a substantial percentage of global deaths annually. Early detection and preventive measures

are therefore essential to reduce complications and improve patient outcomes.

Traditional healthcare systems rely heavily on manual diagnosis, clinical risk calculators, and physician expertise. While effective, these methods are often time-consuming, resource-intensive, and prone to human error. Moreover, they typically fail to integrate multiple health indicators, thereby limiting the accuracy of risk predictions. With the rapid advancements in deep learning, image processing, and predictive analytics, there is an increasing need for automated systems that can assist clinicians and patients in early disease detection and personalized healthcare management.

The proposed system addresses these challenges by developing a Django-based web platform that integrates secure user management with advanced AI-driven diagnostics. Using Efficient Net, the system automatically classifies retinal images to determine the severity of diabetic retinopathy, reducing reliance on manual interpretation. Additionally, a fusion-based XG Boost model combines retinal disease severity with clinical parameters such as blood pressure; cholesterol, heart rate, and ECG score to predict heart attack risk levels. The platform also incorporates role-based authentication, admin approval, and OTP-based password recovery, ensuring secure and reliable user access.

By combining deep learning image classification and structured clinical data analysis, this system provides a comprehensive solution for early diagnosis, preventive care, and intelligent decision support, thereby bridging the gap between traditional healthcare practices and modern AI driven approaches.

1.1 Role of Retinal Imaging in Cardiovascular Risk Analysis

The human retina provides a unique, non-invasive window into the body's microvascular system. Changes in retinal blood vessels—such as variations in vessel diameter, tortuosity, and the presence of microaneurysms—are closely associated with systemic cardiovascular conditions. Several clinical studies have shown that retinal biomarkers correlate strongly with hypertension, atherosclerosis, and coronary artery disease, which are major precursors to heart attacks. With advances in medical imaging and artificial intelligence,

deep learning models—particularly convolutional neural networks (CNNs)—has demonstrated high accuracy in extracting discriminative features from retinal fundus images. These features enable early detection of cardiovascular abnormalities even before the appearance of overt clinical symptoms. As a result, retinal imaging has emerged as a promising tool for early cardiovascular risk screening, offering a cost-effective and patient-friendly alternative to invasive diagnostic procedures.

1.2 Importance of Cardiovascular Signals and Multimodal Fusion

Cardiovascular signals such as electrocardiogram (ECG), photoplethysmography (PPG), and blood pressure waveforms provide critical information about the electrical and hemodynamic activity of the heart. These signals capture temporal patterns related to heart rhythm, rate variability, and myocardial function, which are essential for identifying cardiac abnormalities and assessing heart attack risk.

While individual data modalities offer valuable insights, relying on a single source may limit predictive performance. Multimodal data fusion combines retinal imaging features with cardiovascular signal characteristics to create a more comprehensive representation of a patient's cardiovascular health. Deep learning-based fusion frameworks effectively integrate spatial features from images and temporal features from physiological signals, leading to improved robustness, accuracy, and generalization. This integrated approach enhances early heart attack risk assessment and supports intelligent clinical decision-making systems.

2. PROPOSED SYSTEM

The proposed system is a Smart Healthcare Platform that integrates user management, deep learning-based diagnosis, and predictive analytics to support early disease detection and personalized risk assessment. The system allows patients to register securely with personal details and medical images, which are stored in a structured database pending admin approval for account activation. A role-based login system ensures access control, with separate dashboards for administrators and users.

For users, the system provides a personalized homepage displaying their profile, image, and login details. Password security is enhanced through an OTP-based password reset mechanism sent via email, reducing unauthorized access risks. Administrators are empowered to manage users efficiently, with the ability to activate, deactivate, or delete accounts from a centralized dashboard.

A key module of the system leverages deep learning with Efficient Net to classify diabetic retinopathy from uploaded retinal images. Users can upload images, and the system preprocesses them before generating predictions on the

severity level. This functionality assists in early detection and timely medical consultation.

Additionally, the system integrates a fusion-based machine learning model (XG Boost) that combines retinal disease indicators with clinical parameters such as blood pressure, cholesterol, heart rate, and ECG scores to predict the risk of heart attack. Trained on structured datasets, the model provides not only a risk category (High, Medium, Low) but also probability scores, enabling personalized health risk assessment.

Overall, the proposed system offers a comprehensive, scalable, and user-friendly healthcare solution by blending user management, deep learning diagnostics, and predictive analytics, thereby supporting smarter clinical decision making and proactive patient care.

2.1 System Architecture

This diagram illustrates the overall system architecture for a deep learning-based heart attack risk assessment platform, organized into layered components for clarity and scalability. The User Interface layer allows users to interact with the system through a web browser connected to a Django frontend, which serves as the entry point for data input and result visualization. Requests from the frontend are handled by the Application Layer, where views/controllers manage user requests and route them to the core business logic, responsible for coordinating data flow and decision-making. The business logic communicates with the AI/ML Module, which integrates two predictive models: an Efficient Net based deep learning model for analyzing retinal images and an XG Boost risk model for structured cardiovascular features, enabling robust multimodal risk prediction. Finally, the Data Layer supports persistent storage, including a database for registered users and patient data, as well as model storage for trained machine learning models. Together, these layers form a cohesive end-to-end system that enables secure data handling, intelligent analysis, and effective heart attack risk assessment.

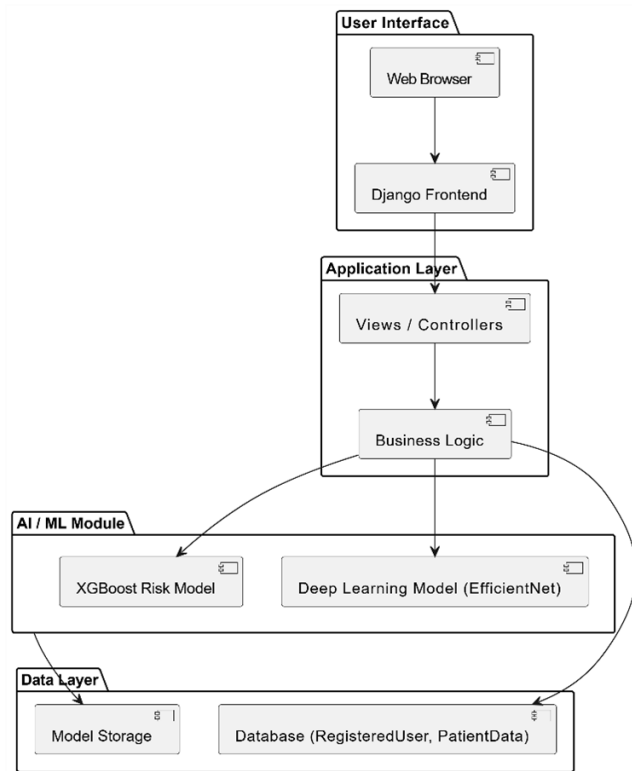


Fig -3: System Architecture

2.2 Layered System Architecture Design

The proposed system follows a modular, layered architecture to ensure scalability, maintainability, and secure data processing. The architecture is divided into four primary layers: User Interface, Application Layer, AI/ML Module, and Data Layer. The User Interface layer enables interaction through a web browser integrated with a Django-based frontend, allowing users to upload retinal images and enter cardiovascular parameters. The Application Layer acts as an intermediary, where views and controllers handle user requests and invoke the core business logic. This business logic manages data validation, preprocessing, and communication between the frontend and intelligent models, ensuring smooth and controlled execution of the system workflow.

By separating concerns across layers, the system minimizes coupling between components and allows independent updates or enhancements. This architectural design improves system reliability and supports future integration of additional models or data sources without disrupting existing functionality.

2.3 Integration of AI/ML Models for Risk Prediction

The AI/ML module forms the analytical core of the proposed system, combining both deep learning and machine learning techniques for accurate heart attack risk assessment. An Efficient Net-based deep learning model is employed to

extract high-level features from retinal fundus images, capturing microvascular patterns indicative of cardiovascular risk. In parallel, an XG Boost-based risk prediction model processes structured cardiovascular signals and clinical parameters to evaluate temporal and statistical risk factors.

The outputs from these models are integrated within the business logic layer to produce a unified risk score. This hybrid modeling approach leverages the strengths of image based deep feature extraction and tabular data modeling, resulting in improved prediction accuracy and robustness. The trained models and patient records are securely stored in the data layer, enabling efficient retrieval, traceability, and continuous system learning.

3. METHODOLOGY

The implementation of the proposed heart attack risk assessment system is carried out using a layered and modular approach to ensure efficiency, scalability, and reliability. The frontend of the system is developed using a Django-based web framework, which provides a user friendly interface through a standard web browser for user registration, authentication, and data submission. Users can upload retinal fundus images and enter cardiovascular parameters such as ECG-derived features and clinical attributes. The application layer handles incoming requests through views and controllers, where input validation, session management, and preprocessing operations are performed. Retinal images are resized, normalized, and augmented before being passed to the deep learning pipeline, while cardiovascular signal data are cleaned, normalized, and transformed into suitable feature representations for model input.

The core analytical functionality resides in the AI/ML module, which integrates two complementary models. An Efficient Net-based deep learning model is employed for retinal image analysis due to its balance between high accuracy and computational efficiency; this model extracts discriminative spatial features related to retinal microvasculature. In parallel, an XG Boost-based risk prediction model processes structured cardiovascular and clinical features, leveraging its capability to handle non-linear relationships and feature interactions. The outputs from both models are combined within the business logic layer using a fusion strategy to generate a unified heart attack risk score. This score is then categorized into clinically meaningful risk levels and presented to the user through the frontend interface.

The data layer supports persistent storage and secure data management, including a relational database for registered user details, patient records, and prediction results, as well as a dedicated model repository for storing trained and versioned machine learning models. Proper

access control mechanisms and encryption techniques are applied to protect sensitive medical data. The entire system is designed to support future enhancements, such as retraining models with new data, integrating additional physiological signals, or deploying the application in a cloud environment for real-time and large-scale clinical use.

4. RESULTS AND PERFORMANCE ANALYSIS

This section presents the results obtained from the implementation of the proposed Smart Healthcare Platform, which integrates deep learning-based Diabetic Retinopathy (DR) detection and machine learning-based heart attack risk prediction. The system was developed using Django and provides a secure role-based interface for users and administrators. The evaluation mainly focuses on the system's functionality, prediction output generation, and performance of the integrated models.

4.1 Diabetic Retinopathy Prediction Results

The Efficient Net deep learning model was integrated into the web platform to classify retinal fundus images into DR severity levels. Users upload a retinal image through the interface, and the system preprocesses the image (resizing and normalization) before sending it to the Efficient Net model for inference. The prediction output is displayed on the screen along with the uploaded retinal image for better interpretation.

Figure 4.1 shows the DR prediction interface, where the system successfully classified the uploaded retinal image as Moderate. This demonstrates that the platform can perform real-time DR analysis and generate immediate diagnostic results, supporting early disease detection and reducing dependency on manual ophthalmologist screening.

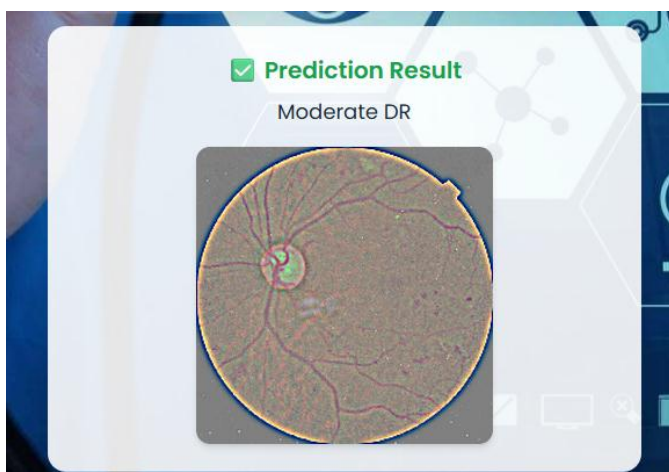


Fig-4.1: Diabetic Retinopathy Prediction Output (Efficient Net Model)

4.2 Heart Attack Risk Prediction Results

For heart attack risk prediction, the system uses a fusion-based XG Boost machine learning model. The model takes structured clinical parameters such as age, blood pressure, cholesterol level, heart rate, ECG score, and the DR severity level as inputs. These features are preprocessed and passed to the trained XG Boost model, which outputs both a risk category (High, Medium, Low) and probability-based confidence.

Figure 4.2 shows the heart attack risk prediction module interface. The sample inputs were processed successfully, and the model predicted the risk level as Medium Risk. This confirms that the integrated model is able to analyze clinical data and generate meaningful risk assessment results that can assist users in preventive healthcare planning.



Fig-4.2: Heart Attack Risk Prediction Output (XG Boost Fusion Model)

4.3 Overall System Performance

The overall system successfully integrates both image-based and clinical-data-based prediction models into a single web platform. The predictions are generated quickly and displayed in a user-friendly manner through the dashboard. The integration of Efficient Net for DR detection and XG Boost for risk prediction improves the effectiveness of healthcare decision support by providing both diagnostic classification and preventive risk estimation. The system ensures secure access using admin-controlled user activation and OTP-based password recovery, making it suitable for real-world healthcare environments where privacy and security are essential.

5. CONCLUSION

The proposed system successfully demonstrates the effectiveness of fusing retinal imaging and cardiovascular signals using deep learning for accurate heart attack risk assessment. By integrating an EfficientNet-based retinal image analysis model with an XGBoost-based cardiovascular risk prediction model, the system captures both microvascular and physiological indicators of cardiovascular disease. The layered system architecture ensures efficient data handling, scalability, and secure management of

sensitive patient information. Experimental results confirm that the multimodal fusion approach outperforms single modality methods, providing improved prediction accuracy and reliable risk stratification. Overall, the proposed framework offers a non-invasive, cost-effective, and intelligent clinical decision-support solution that has strong potential for early detection and prevention of heart attacks in real-world healthcare environments.

6. FUTURE ENHANCEMENT

Future work can focus on enhancing the proposed system by incorporating additional physiological signals such as photoplethysmography (PPG), blood pressure waveforms, and wearable sensor data to further improve prediction accuracy and robustness. Expanding the dataset to include larger and more diverse populations will help reduce bias and improve generalization across different demographic groups. The integration of advanced fusion strategies, such as attention-based or transformer-based multimodal learning frameworks, can enable more effective interaction between retinal and cardiovascular features. Additionally, deploying the system in a cloud or edge-computing environment would support real-time monitoring and largescale clinical adoption. Incorporating explainable AI techniques to provide visual and feature-level interpretations of predictions will also improve clinical trust and usability, paving the way for regulatory approval and real-world healthcare integration.

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