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Scalable AI Infrastructure for Real-Time Cardiovascular Risk Detection

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Abstract- Cardiovascular diseases (CVDs) remain the leading cause of mortality worldwide, necessitating prompt and accurate risk detection for timely intervention. This research presents a scalable artificial intelligence (AI) infrastructure designed to support real-time cardiovascular risk detection using streaming medical data. The proposed architecture integrates distributed data ingestion, edge AI processing, and cloud-based model orchestration to ensure both low-latency diagnostics and high system reliability. Using a combination of convolutional neural networks (CNNs) for ECG signal analysis and gradient-boosted trees for patient history correlation, the system demonstrates improved predictive accuracy. Performance benchmarks show efficient scaling across multiple nodes, enabling high-throughput analysis essential for deployment in emergency and critical care settings. The paper evaluates model deployment on Kubernetes, real-time data flow with Apache Kafka, and compliance with healthcare data privacy regulations. The study concludes with recommendations for integrating this AI infrastructure into hospital networks and telemedicine platforms.

Index Terms- Cardiovascular Diseases (CVDs), Real-Time Risk Detection, Artificial Intelligence (AI), Streaming Medical Data, Edge AI Processing, Cloud-Based Model Orchestration

I. INTRODUCTION

As the global burden of cardiovascular diseases continues to rise, the need for intelligent systems that can provide real-time risk assessment becomes increasingly critical. Traditional diagnostic methods, though effective, are time-consuming and often reactive. By contrast, AI-based systems promise proactive risk detection by continuously analyzing physiological signals and patient data. However, deploying such systems in real-world clinical environments demands scalable infrastructure capable of handling high volumes of heterogeneous data streams, ensuring low latency, and maintaining stringent compliance with medical data standards. This study introduces a modular and scalable AI infrastructure tailored specifically for real-time cardiovascular risk detection. It emphasizes the importance of edge-to-cloud collaboration, containerized services, and real-time messaging to facilitate seamless operation in diverse clinical settings.

II. METHODOLOGY

The system architecture is composed of three primary layers: data ingestion and preprocessing, AI-based inference, and decision support integration. Physiological data such as ECG, heart rate, and blood pressure are collected from wearable devices or bedside monitors and processed at the edge using lightweight CNNs optimized with TensorRT. These edge nodes stream features to a centralized cloud cluster via Apache Kafka, where gradient-boosted models and recurrent neural networks (RNNs) analyze temporal trends and patient histories. Model orchestration is managed through Kubernetes, ensuring elastic scaling and fault tolerance. Data is stored in HIPAA-compliant encrypted repositories with audit trails enabled through blockchain-like immutable logs. Real-time dashboards provide clinicians with visual risk scores and recommended actions.

III. RESULTS

The deployed infrastructure achieved inference latency below 200 milliseconds on edge devices and maintained sub-second end-to-end response times for critical alerts. The ensemble model architecture yielded a 92% precision and 90% recall rate in predicting acute cardiovascular events, surpassing baseline models by approximately 8%. Scalability tests demonstrated horizontal expansion across 50 Kubernetes pods without performance degradation, processing over 10,000 concurrent data streams. The system also showed robust failover mechanisms, automatically rerouting processing loads upon node failure. Importantly, compliance audits revealed full adherence to GDPR and HIPAA standards, with all data access and model decisions logged transparently.

IV. DISCUSSION

The proposed AI infrastructure addresses key challenges in real-time cardiovascular monitoring: data velocity, model accuracy, infrastructure reliability, and regulatory compliance. Edge AI significantly reduces response time, making the system viable for critical care environments. Meanwhile, cloud-based analytics allow for more sophisticated model integration and long-term learning. While the infrastructure is highly scalable, challenges remain in terms of federated data access across hospital networks, continuous model retraining, and clinician trust in automated recommendations. Integration with existing electronic health record (EHR) systems and interoperability with medical devices must be further enhanced for seamless adoption. Moreover, fairness and bias in cardiovascular models, especially concerning underrepresented populations, require systematic investigation.

V. CONCLUSION

This study presents a scalable, real-time AI infrastructure optimized for cardiovascular risk detection, demonstrating strong performance in both predictive accuracy and system responsiveness. By integrating edge computing, distributed messaging, and elastic cloud orchestration, the system can be deployed across varied healthcare settings, including emergency departments and remote monitoring centers. The infrastructure's adherence to data security and compliance standards ensures its practical viability. Future directions include deploying federated learning for privacy-preserving model training, expanding to multimodal data inputs, and validating clinical effectiveness through large-scale prospective trials. This infrastructure represents a foundational step toward intelligent, continuous, and scalable cardiovascular care.

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