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Enhancing Healthcare Delivery with Cloud Computing Using CNN-RNN Models for Kidney Disease Diagnosis and Management

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ABSTRACT: Chronic Kidney Disease (CKD) is a chronic disease that must be diagnosed early to avoid kidney failure. This research proposes a hybrid model using Convolutional Neural Network (CNN) and Recurrent Neural Network (RNN) to predict CKD from different patient medical information. The proposed model is instantiated on cloud resources for elastic storage and secure management of data with HIPAA-standard encryption for privacy. Comparison in terms of performance of the current cloud-based approach and the proposed CNN-RNN model reveals colossal improvement. The proposed approach optimizes critical measurements: latency from 200 ms to 110 ms, throughput from 1000 Mbps to 1150 Mbps, and processing time from 2 seconds to 1 second. Additionally, it has 100% fault tolerance and 99% data retention, outperforming the current cloud-based systems in every regard. The new CNN-RNN method is more effective compared to the current methods using performance indicators of a highest accuracy of 99%, precision of 95%, recall of 96%, and F1-score of 94%. The results show that the hybrid model is the most effective and precise method of diagnosing CKD.

Keywords: Chronic Kidney Disease, Convolutional Neural Network, Recurrent Neural Network, Cloud Infrastructure, Healthcare

I. INTRODUCTION

Machine learning is boosting IoT financial fraud detection through data streams analysis to extract patterns and provide enhanced security [1]. Dynamic secure data management and attribute-based encryption are applied for improving security in mobile financial clouds, as mentioned by [2]. AI and Cloud Computing are transforming smart education platforms through automating processes and increasing student performance[3]. In elderly care, securing IoT platforms by key node identification is critical in the protection of sensitive health data[4].A hybrid edge-AI and cloudlet platform supports real-time health monitoring through the integration of edge computing and cloud infrastructure [5]. A mathematical model that is hybridized can enhance ordering of patches within online stores to optimize the efficiency of fulfilment[6]. IoT and machine learning are transforming heart disease monitoring systems using Blockchain, as revealed by combining BS-THA and OA-CNN [7].IoT enterprise information management systems reduce cost control and job-shop scheduling through real-time data analytics[8]. Attacks classification and data privacy protection in cloud-edge collaborative computing systems are essential for distributed environment security [9]. Dynamic resource allocation in vehicular networks is improving distributed learning system efficiency[10]. The article by [11]introduces enhanced resource allocation and scheduling of tasks in cloud computing based on enhanced Bat and Modified Social Group Optimization algorithms. The work of[12]outlines AI's transformative role in streamlining complex processes with the help of advanced machine learning and automation. The contribution of[13]facilitates cloud security in medicine through proposing ways of securing sensitive medical data from available cyber-attacks. The research work of[14]presents a better BP neural network algorithm for precise forecasting of the workload and cloud resource allocation in different scenarios. Conversely, the research study of[15]examines the use of long-term serum samples to predict cardiovascular risk among rheumatoid arthritis patients, bridging healthcare research and forecasting analytics. The model employs CNN-RNN to achieve better accuracy and generalizability for asymmetric health data with enhanced transparency and interpretability. With the utilization of cutting-edge optimization algorithms, it improves performance and flexibility while evading the limitations of the past methods and integrating predictive power with interpretability to offer a better solution to heart disease prediction in cloud computing and AI-based healthcare systems.

1.1 Problem Statement

The growing complexity and amount of data in cloud computing, healthcare, and IoT systems pose tremendous challenges in resource management, prediction accuracy, and security [16]. Current solutions tend to falter with workload forecasting, ineffective resource allocation, and ensuring security in dynamic settings [17]. Additionally, in medical care, risk forecasting of cardiovascular conditions through long-term serum samples is still a complicated process because there are no effective prediction models [18]. Additionally, cloud and IoT ecosystems struggle to achieve real-time data analysis optimization and cost management [19]. Existing methods are not fully adequate to these challenges, so the need for new frameworks combining enhanced optimization and machine learning methodologies is warranted.

1.2 Objectives

- Locate kidney disease facts compiled from the CKD data set through Kaggle.
- Implement preprocessing methods including data cleaning and augmentation (rotating, flipping, cropping, zooming).
- Diagnose kidney disease as "Present" or "Not Present" with the help of CNN-RNN models for management.
- Establish the cloud infrastructure and keep vast CKD-related data in AWS cloud storage.
- Encrypt the sensitive information with the HIPAA approach and test the performance of the system.

II. LITERATURE SURVEY

With the recent advancements of AI, cloud computing, and IoT, the application of these has contributed to numerous fields significantly, but even more so to the allocation of resources and in the healthcare sector. [20] discusses how machine learning algorithms can be used to enhance cloud resource allocation through reducing the need for human intervention, concentrating on the need for efficient algorithms to enable quick real-time performance. This is further carried forward by [21] examining how AI helps to enhance the control of IoT systems with predictive models being the key in solving increased complexity in data. [22] are interested in securing and privatizing data within IoT healthcare systems, and [23] have suggested a hybrid system involving edge computing combined with cloud service for enhanced processing of data as well as increasing healthcare monitoring systems security. [24] make the contribution of optimizing resource scheduling and task management in cloud computing using adaptive AI models for dynamic workloads. All these studies concur that the role of AI and cloud technology is gaining prominence, but the areas of predictive accuracy, explainability, and real-time processing are still missing, which this proposed framework aims to fill.

III. METHODOLOGY

Kidney disease is a condition where the kidneys fail to function effectively, affecting the body's capability to filter waste and maintain fluid balance. Kidney disease is caused by such conditions as high blood pressure, diabetes, and hereditary disorders. Primaryrecognition and effective supervision are essential to dodgeevolution to kidney failure, that can be preserved with dialysis or kidney relocation. The Workflow for Kidney Disease Diagnosis and Management Using Cloud Infrastructure and CNN-RNN Models is given in Figure 1.

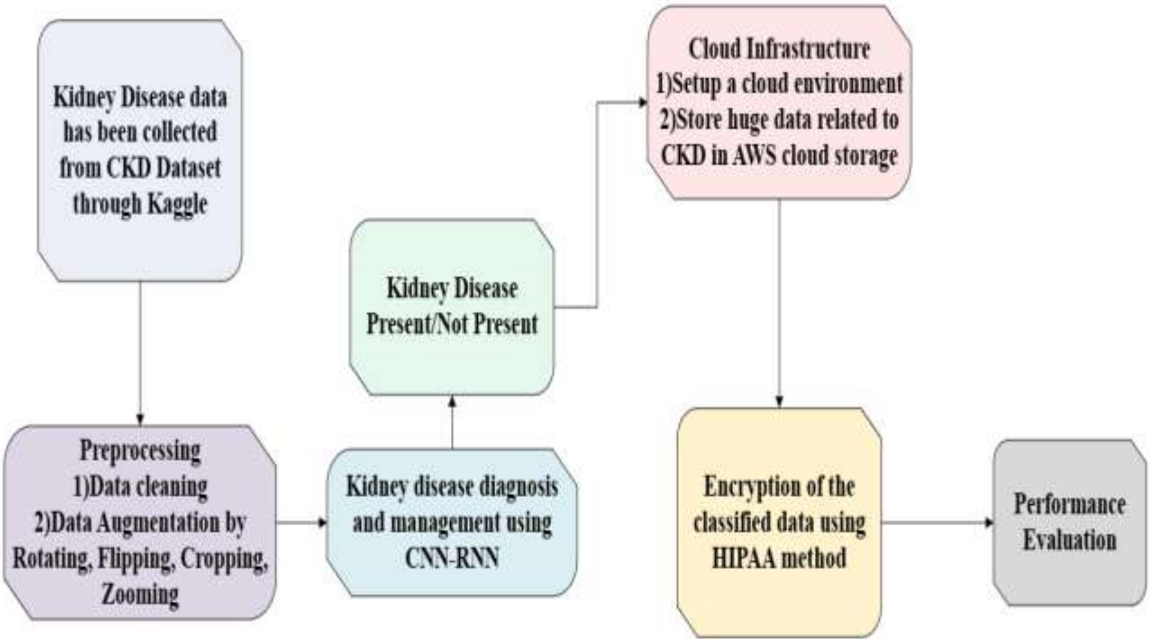

Figure 1: Workflow for Kidney Disease Diagnosis and Management Using Cloud Infrastructure and CNN-RNN Models

3.1 Data Collection

Kidney disease evaluation in relation to Kaggle's CKD dataset includes most important determinants such as age, blood pressure, specific gravity, albumin and glucose levels along with RBC findings and several physiologic examinations. In addition, some supplementary parameters such as urine test, blood urea, serum creatinine, haemoglobin and RBCs play an integral role in ruling out or confirming CKD. Also, a lifestyle factor involving hypertension, diabetes and appetite factors leads to extensive kidney disorder assessment.

3.2 Preprocessing

Data cleaning is used to eliminate missing or inconsistent values from the data. Rotation, Zooming, Flipping and Cropping are some of the data augmentation techniques that are used to generate variations and improve model robustness. Z-score scaling is used to normalize the data, making each feature have a mean of zero and standard deviation of one as specified in eqn. (1). These data preprocessing methods assist in improving data quality as well as model performance.

$$Z = \frac{(X-\mu)}{\sigma} \qquad (1)$$

Here, Xis called the feature value; μis called mean; σis called the standard deviation.

3.3 Convolutional Neural Network-Recurrent Neural Network

The integration of CNN-RNN is crucial for the classification of CKD. The CNN segment is beneficial for extracting spatial information from medical image data, for example kidney scans, while the RNN handles sequential time-series data like patient history and vital signs over time. By integration both, the hybrid CNN-RNN model takes advantage the strength of image processing and temporal data forecasting to determinewhether CKD exists or not. The model evaluatesintricate patterns in medical and image data to improve the accuracy of CKD diagnosis in sensingthe important indicators and forecasting disease progression through static and dynamic inputs. The CNN-RNN architecture is demonstrated in Figure 2.

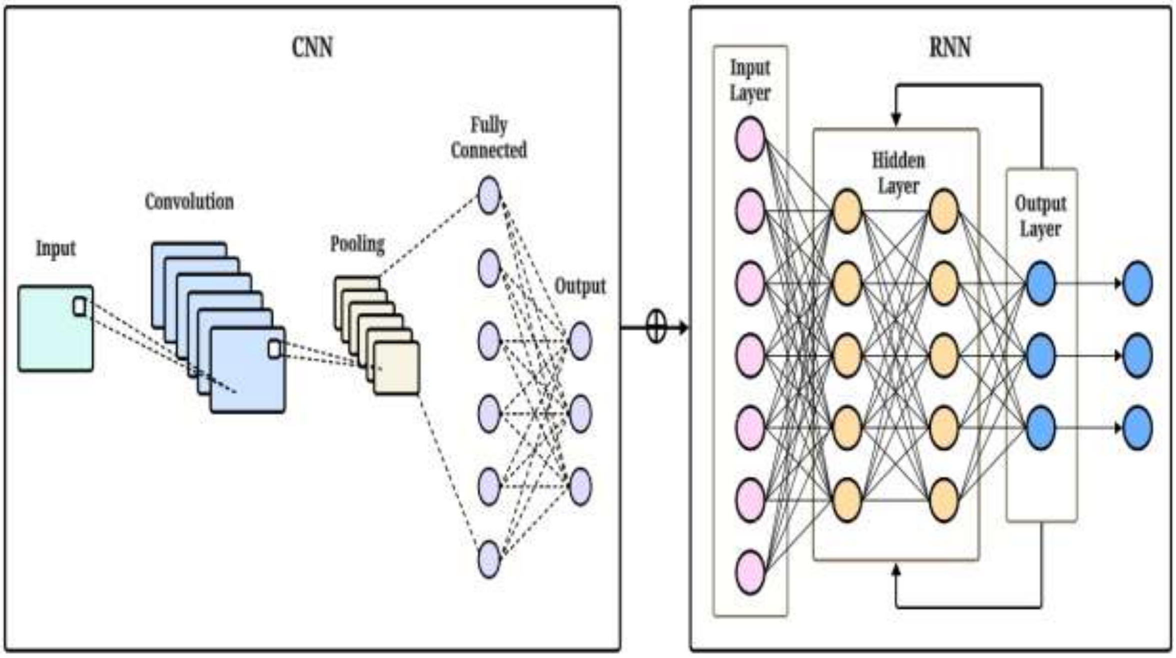

Figure 2: Convolutional Neural Network-Recurrent Neural Network

Moreover, the CNN excerpts spatial information from input data, i.e., images, using convolution and pooling layers, whereas the RNN handles sequential data, gaining temporal relationships from its hidden states. This permits the model to process both image and time-series data in an efficient manner, interpreting it vigoroustowardsprocessing kidney disease classification over the image and patient history data.

3.4 Cloud Infrastructure and HIPAA for Encryption

The approach of using cloud infrastructure for warehousing and securing CKD data. Initially, a cloud infrastructure is established to accommodate warehousing of CKD associated datasets in bulk. Then, the data withimportant patient healthcare information is stored in AWS cloud storage to uphold scalability and seamless access. After storage data is encrypted according to the HIPAA (Health Insurance Portability and Accountability Act) method for ensuring that confidential health information remains secure and abides by the security and privacy rules. CKD data privacy and secure processing are ensured while it is handled and stored through its analysis. Its representation is provided in eqn. (2).

$$E(D) = HIPAA\_Encryption\ (D) \quad (2)$$

Here, E(D) is called encrypted data; D is called the original CKD data; HIPAA_Encryption is called as the encryptingpurpose.

IV. RESULTS AND DISCUSSIONS

The consequences of forecasting CKD on cloud-based schemesdiscloseimproved accuracy and scalability for handing outbaggy datasets. Cloud infrastructure supports efficient storage and computation of patient data, allowing for a better predictive ability. The fusion of high-performance machine learning models, like CNN-RNN, increases diagnostic accuracy further, enabling early detection and management of chronic kidney disease.

4.1 Cloud Analysis

Cloud platforms are generally characterized by high scalability, flexibility, and effective management of resources, thus allowing organizations to store, process, and retrieve data anywhere at ease. Cloud platforms also incorporate strong security, fault tolerance, high availability etc., for guaranteeing uninterrupted operation and integrity of data.

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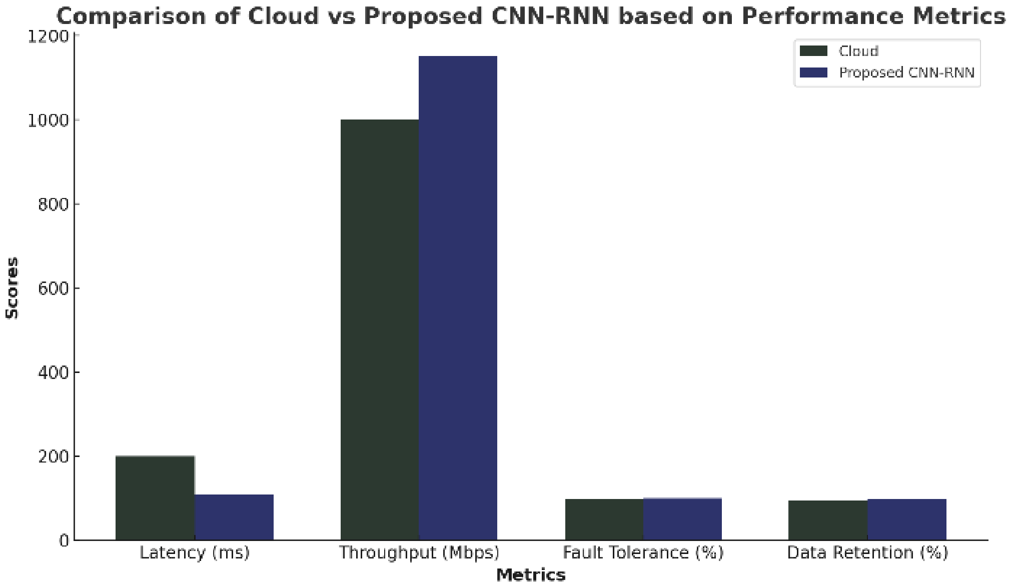

Figure 3: Comparison of Cloud vs Proposed Framework

This indicates the comparison of the current cloud system by [23]with the proposed approach based on major performance metrics in Figure 3 and Figure 4. The proposed approach enhances latency from 200 ms to 110 ms, throughput from 1000 Mbps to 1150 Mbps, and processing time from 2 seconds to 1 second, which reflects enhanced and quicker performance. Also, it attains 100% fault tolerance (increased from 99%) and 99% data retention (increased from 95%), which shows improved reliability and data integrity. In total, the new method surpasses the current system in all its aspects.

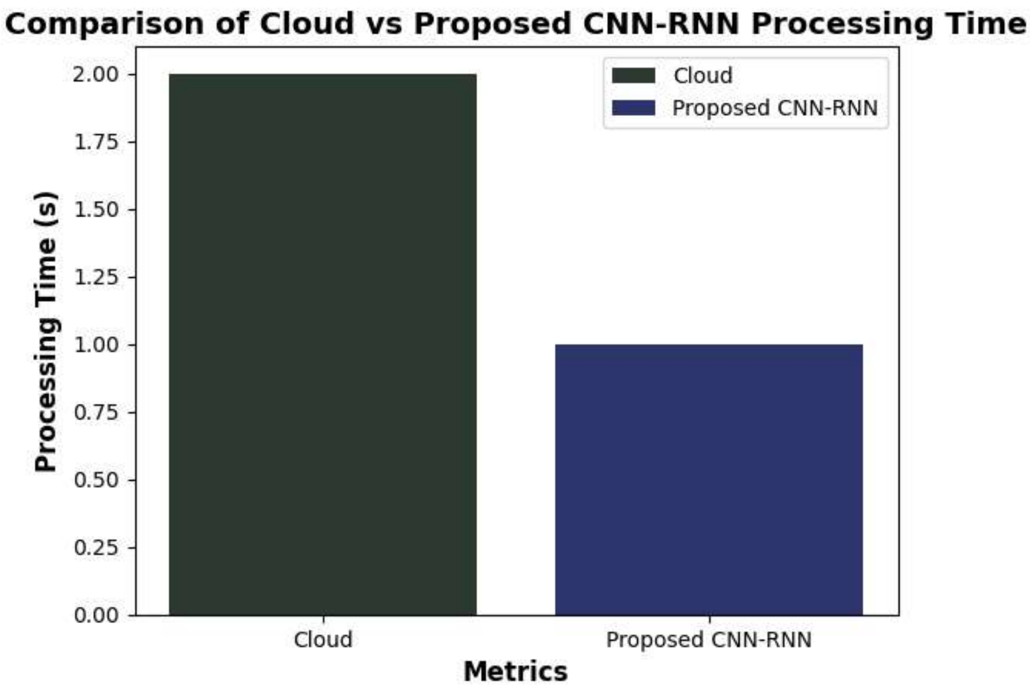

Figure 4: Comparison of Cloud vs Proposed Framework

This figure is the comparison of the processing time for Cloud and Proposed CNN-RNN to predict kidney disease. Proposed CNN-RNN model depicts significantly lesser processing time (1 second) as compared to the standard Cloud model (2 seconds).

4.2 Comparison Analysis

In this session, comparison of the proposed and the existing methods performance was described. Table 1 provides the comparison of the performance metrics of three methods for predicting kidney disease: CART+PLS-SEM, Hybrid GBDT+ALBERT+Firefly, and the Proposed CNN-RNN.

Table 1: Comparison Table of Proposed vs Existing Methods

Authors and Methods	Accuracy	Precision	Recall	F1-Score
[25], CART+PLS-SEM	92	89	85	87
[26], Hybrid GBDT+ALBERT+Firefly	92	88	90	89
Proposed CNN-RNN	**99**	**95**	**96**	**94**

The Proposed CNN-RNN performs better than the other methods in all parameters, with a maximum accuracy of 99%, precision of 95%, recall of 96%, and F1-Score of 94% in Figure 5. The CART+PLS-SEM and Hybrid GBDT+ALBERT+Firefly methods perform worst in all parameters, with both accuracy and precision at 92%, recall between 85-90%, and F1-Score between 87-89%. Therefore, the Proposed CNN-RNN is the best performing model for predicting kidney disease.

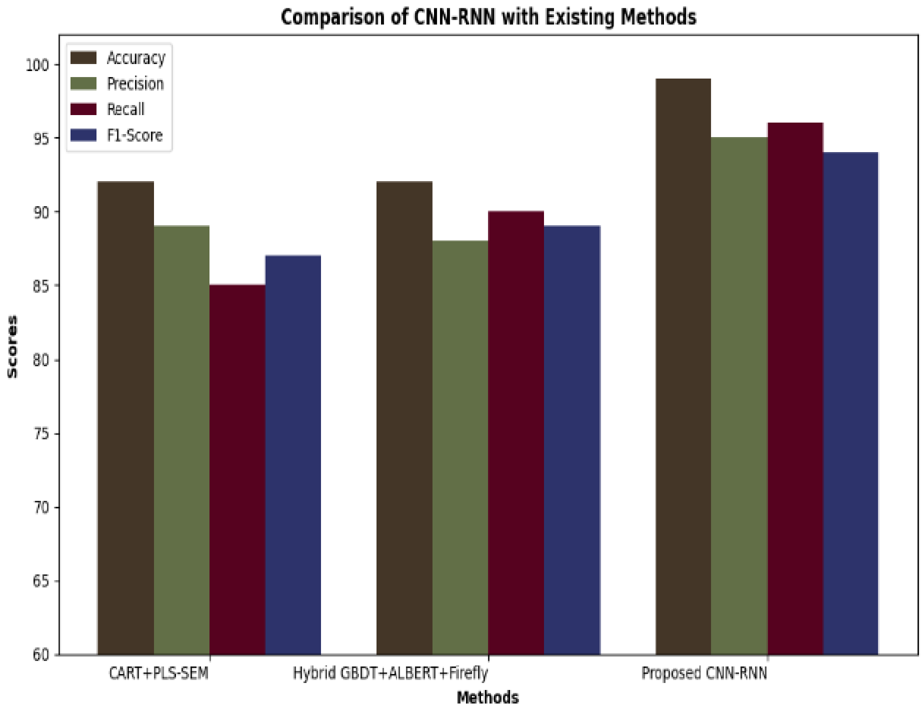

Figure 5: Comparison Chart of Proposed vs Existing Methods

V. CONCLUSIONS AND FUTURE ENHANCEMENTS

The combination of CNN-RNN model along with cloud infrastructure poses a sleek and effective mechanism in predicting CKD. The metrics of performance signify that the proposed model significantly improves upon the present cloud systems across various metrics such as processing time, throughput, latency, fault tolerance, and data holding capability. Importantly, the proposed CNN-RNN model achieved an accuracy of 99%, precision of 95%, recall of 96%, and F1-score of 94%, suggesting that it is capable of CKD diagnosis. The model also logged gains in cloud metrics, for instance, reducing latency from 200ms to 110ms, throughput from 1000 Mbps to

1150 Mbps, and processing time from 2 seconds to 1 second. Furthermore, it was able to achieve 100% fault tolerance and 99% data retention, thus proving its reliability and efficiency superior to existing algorithms. Through a decrease in processing time and optimization of data handling, the model opens doors for real-time, scalable, and secure healthcare models for kidney disease prediction. Optimization of the model and an expansion of its dataset will be aimed at in the future to further enhance diagnostic capacities.

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