Chronic Kidney Disease Prediction Using Machine Learning Algorithms

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***Abstract*— Chronic Kidney Disease (CKD) is a prevalent global health condition primarily caused by hypertension and diabetes, posing a significant risk of premature mortality. The timely identification of CKD and its associated disorders is a challenging task for medical practitioners aiming to prevent disease progression. This study focuses on developing a diagnostic approach for chronic renal ailments, aiming to enable early intervention and mitigate the progression of CKD. With a dataset comprising 400 individuals and 24 variables, this investigation employs statistical analysis techniques to handle missing data and utilizes the Recursive Feature Elimination (RFE) method for feature selection. Classification techniques, including k-nearest neighbors (KNN), Random Forest Classifier (RFC), and Ada Boost Classifier (ABC), are employed to evaluate the dataset. Results demonstrate promising performance across all metrics, with the RFC and ABC algorithms achieving perfect scores of 100% in accuracy, precision, recall, and F1-score. Machine learning techniques significantly contribute to the prompt detection of CKD, empowering healthcare practitioners to identify symptoms promptly and prevent renal failure.**

***Index Terms*—Machine Learning, KNN, RFC, ABC and Prediction Values.**

I. INTRODUCTION

Chronic kidney disease (CKD) is a global health challenge characterized by impaired kidney function, leading to the accumulation of fluid and waste in the body and increasing the risk of heart disease and stroke. With its prevalence and impact on mortality on the rise, CKD has become one of the most significant diseases worldwide. From 1990 to 2013, CKD ranked as the 13th leading cause of death globally, with an alarming 90% annual increase in mortality rates. Currently, approximately 850 million people worldwide are affected by kidney disease, contributing to an estimated 2.4 million deaths annually. Notably, CKD has emerged as the sixth-fastest-growing cause of global fatalities, posing a substantial public health hazard. The burden of CKD disproportionately affects low-income countries that face challenges in detection, prevention, and treatment. Factors such as limited access to clean water, malnutrition, and a lack of physical activity contribute to the high prevalence of CKD, particularly in countries like Ethiopia, where hundreds of thousands of individuals are affected. In 2017 alone, renal disease claimed the lives of 4,875 Ethiopians, highlighting the urgent need for improved strategies to address this pressing issue. With a mortality rate of 0.77 percent, ranking 138th in the world, Ethiopia faces significant challenges in combating CKD. By 2018, the nation's age-adjusted mortality rate had risen to 8.46, with a death rate of 12.70 per 100,000 inhabitants, positioning CKD as a growing concern.

CKD is commonly classified into five stages by the National Kidney Foundation based on glomerular filtration rate (GFR) and abnormal renal function, ranging from mild symptoms in stage 1 to renal failure in stage 5. The costs associated with renal replacement therapy (RRT) for total renal failure are substantial, making it a significant financial burden for underdeveloped nations like Ethiopia that lack resources, medical expertise, and affordable treatment options. It is estimated that in the United States, 37 million adults have CKD, with a significant portion of them going untreated. Furthermore, 40% of non-dialysis patients with significant renal impairment are unaware of their CKD status. The impact is further reflected in healthcare costs, with Medicare users alone incurring $87.2 billion in expenses related to CKD in 2019, while those with end-stage renal disease (ESRD) cost $37.3 billion.

Early identification of CKD is crucial to reducing costs and improving treatment outcomes. Predictive analysis and

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machine learning techniques offer promising avenues for early detection and enhanced therapy. In this study, we explore the application of the Random Forest (RF), K-Nearest Neighbors (KNN), and AdaBoost classifier (ABC) in diagnosing CKD. By leveraging these advanced computational methods, we aim to improve the accuracy of CKD detection, providing clinicians with valuable insights for effective treatment strategies. Previous research has often focused on two distinct CKD groups, limiting the generalizability of treatment recommendations. Therefore, this study addresses this gap by adopting a comprehensive approach to detecting CKD and developing robust treatment protocols.

II. Literature Survey

In their study, Ajith Kumar, C. Hari Haran, and D. Manu Vignesh (2022) posited that chronic kidney disease (CKD) represents a significant global health challenge, characterised by elevated morbidity and mortality rates and a predisposition to diverse comorbidities. Patients with chronic kidney disease (CKD) frequently overlooked seeking medical intervention for the condition, as there were no significant adverse effects observed during the initial phases. The timely identification of chronic kidney disease (CKD) enabled patients to receive appropriate interventions that could potentially ameliorate the progression of the condition. The rapid and accurate diagnostic capabilities of machine learning models have shown promise in aiding clinicians in achieving their objectives. Kumar et al. (Year) proposed the application of various machine learning algorithms, including KNN, logistic regression, decision tree, and random forest, among others, for the purpose of diagnosing CKD, as outlined in their literature review.

Vijendra Singh, Vijayan K. Asari, and Rajkumar Rajasekarana (2022) conducted an analysis in their study, which revealed that chronic kidney disease (CKD) is primarily caused by diabetes and high blood pressure. Globally, scholars used glomerular filtration rate (GFR) and biomarkers of kidney damage to diagnose chronic kidney disease (CKD) as a pathological state characterised by gradual deterioration of renal function. Chronic kidney disease (CKD) is associated with an increased likelihood of premature mortality. Early-stage identification of the diverse ailments linked with CKD posed a formidable obstacle for medical practitioners to impede the progression of the disease. Singh et al. (Year) introduced a novel deep-learning model to tackle this concern, aimed at the early detection and prediction of CKD. The objective of their study was to construct a sophisticated neural network and evaluate its efficacy in comparison to other modern methods of machine learning. The imputation technique of replacing missing values in the database was executed by utilising the mean value of the corresponding features. The optimal parameters of the neural network were determined via parameter tuning and multiple iterations. The study utilised recursive feature elimination (RFE) to identify the most significant features. The selected features comprised haemoglobin, specific gravity, serum creatinine, red blood cell count, albumin, packed cell volume, and hypertension. The aforementioned features were employed for classification objectives in the machine learning models. The deep neural model demonstrated a higher level of performance in comparison to other classifiers such as support vector machines (SVM), K-nearest neighbour (KNN), logistic regression, random forest, and naive Bayes classifiers. It was able to achieve an accuracy of 100%. The aforementioned methodology exhibits considerable promise in facilitating nephrologists identification of chronic kidney disease (CKD).

In their study, Bin Zhang, MD, Chun-song Cheng, Ph.D., Min-gang Ye, MD, Cheng-zheng Han, MD, Dai-yin Peng, Ph.D. (2018) put forth the proposition that Wuqinxi, a traditional medicinal exercise that has been extensively practised in China, exhibited notable rehabilitative outcomes. Wuqinxi has been integrated into physical education curricula across 24 Chinese Medicine university campuses, providing benefits to a population exceeding 1.2 million individuals over an extended period. The aim of their study was to assess the beneficial impacts of Wuqinxi on the physical wellness of female undergraduates. The study involved the use of infrared scanners to conduct real-time monitoring of body calorie dynamics, while electromyography (EMG) was used to measure the iEMG in specific muscles. Furthermore, the inquiry entailed an evaluation of physiological health components, including heart rate and cardiopulmonary performance. The results indicated that the practise of Wuqinxi exercise improved overall bodily function by facilitating more efficient engagement of abdominal muscles, back muscles, and limb strength. Moreover, it enhanced the muscular coordination and equilibrium of the athletes. The study observed a cohort of individuals with varying durations of practise and noted significant enhancements in their physical abilities across a range of exercises, including but not limited to the 800 m run, setting flexion, set-ups, and grip strength. The use of gymnastics derived from the ancient Chinese Wuqinxi exercise has been found to enhance the physical health of female college students. This suggests that it has potential for utilisation in the future for the development of higher education's health quality.

According to a study conducted by Ebrahime Mohammed Senan, Mosleh Hmoud Al-Adhaileh, et al. (2021), chronic kidney disease (CKD) is one of the leading causes of mortality globally, with a prevalence of approximately 10% among adults. Chronic kidney disease (CKD) is a pathological condition that interferes with the normal functioning of the kidneys, thereby requiring efficient predictive measures for timely diagnosis. The objective of this research was to create a diagnostic system that employs machine learning methodologies for the detection of chronic kidney disease (CKD). This system is intended to aid professionals in investigating preventative measures. The research was centred on the assessment of a dataset comprising 400 patients and 24 distinct features. The statistical analysis methods of mean and mode were utilised to replace missing numerical and nominal values. The Recursive Feature Elimination (RFE) technique was utilised to identify and choose the most significant features. Four distinct classification algorithms, namely support vector machine (SVM), k-nearest neighbours (KNN), decision tree, and random forest, were utilised. The various classification algorithms exhibited favourable performance, with the random forest algorithm surpassing the rest by attaining 100% accuracy, precision, recall, and F1-score. Given the gravity of chronic kidney disease (CKD) as a potentially fatal condition associated with significant morbidity and mortality rates, the timely identification enabled by artificial intelligence methodologies is of paramount significance. The utilisation of these techniques has demonstrated significant utility for professionals and medical practitioners in the prompt identification of chronic kidney disease (CKD), thereby mitigating the progression of the condition to end-stage renal disease.

In their publication, Gabriel R. Vásquez-Morales, Sergio M. Martínez-Monterrubio, Pablo Moreno-Ger, and Juan A. Recio-García (2019) introduced a novel neural network-based classifier designed to predict the likelihood of developing chronic kidney disease (CKD). The model underwent training through the utilisation of demographic data and medical care information obtained from two distinct population cohorts. The first cohort consisted of individuals who were diagnosed with CKD in Colombia during the year 2018. The second cohort was comprised of a sample of individuals who did not receive a CKD diagnosis. Upon conducting model training and evaluation using classification algorithms, a test dataset accuracy of 95% was achieved, suggesting the model's potential for disease prognosis. Notwithstanding the demonstrated efficacy of neural networks in predicting CKD, their results were deficient in interpretability, thereby presenting difficulties for domain specialists. In order to overcome this constraint, the scholarly article suggests the utilisation of a dual system that integrates opaque machine learning techniques with a transparent approach, specifically case-based reasoning (CBR), which furnishes justifications for the anticipated outcomes. Through the use of a NN-CBR dual system to explicate predictions of chronic kidney disease (CKD), the study has identified a cohort of 3,494,516 individuals in Colombia who are susceptible to developing CKD, which accounts for approximately 7% of the entire population.

According to the research conducted by Ramesh Chandra Poonia, Mukesh Kumar Gupta, and their colleagues (2022), kidney disease has become a noteworthy issue in terms of public health. The renal organs perform a crucial function in eliminating harmful substances from the organism via the excretion of urine. Although asymptomatic in the initial phases, patients may encounter formidable obstacles during the advanced stages of recuperation. Prompt identification of this ailment is imperative to preserving the lives of individuals. Diverse techniques have been utilised by scholars to identify kidney disease at an early stage. Among these, machine learning-based prediction analysis has exhibited greater precision in contrast to alternative methodologies. The objective of this study was to develop a predictive model based on features to identify the presence of kidney disease. Various machine learning algorithms, such as the k-nearest neighbour algorithm (KNN), artificial neural networks (ANN), support vector machines (SVM), Naive Bayes (NB), and other similar techniques, were employed in conjunction with recursive feature elimination (RFE) and Chi-Square test feature selection techniques. The predictive model based on logistic regression, which integrated optimal features selected through the Chi-Square method, demonstrated the greatest level of accuracy, reaching 98.75 percent. The prominent characteristics encompassed in the analysis were the white blood cell count (WBCC) and blood glucose random (BGR).

III. PROPOSED SYSTEM

Chronic kidney disease is diagnosed through the use of KNN Classification, Random Forest, and Ada Boost Classifier algorithms. These algorithms are employed to achieve optimal outcomes with a high degree of accuracy. Notably, the Random Forest and Ada Boost Classifier algorithms exhibit the highest levels of accuracy, precision, and f-measure. The CKD dataset can be utilised for the analysis and enhancement of the aforementioned subject matter. By utilising the parameters, it is possible to analyse the dataset pertaining to CKD or non-CKD, thereby yielding the outcome.

- DATA PROCESSING

In order to streamline computer processing, nominal variables are encoded. The values of RBC (red blood cells) and pc (p-cresyl) have been assigned binary codes, where 1 represents the everyday category and 0 represents the strange category. The values assigned to the variables % and Ba (barium) denote the presence or absence of a gift, which have been encoded as 1 and 0, respectively. The values for hypertension, dm (diabetes mellitus), cad (coronary artery disease), pe (pulmonary embolism), and ane (acute necrotizing encephalopathy) have been assigned binary codes of 1 and 0 to indicate the presence or absence of the respective conditions. The values of 1 and 0 have been assigned to the terms "proper" and "negative", respectively, for the cost of one unit of an applet. Despite the categorization of three variables, namely sg (specific gravity), al (aluminium), and su (sulphur), as distinct types in the unique statistics description, their values are inherently numeric. Consequently, these variables were treated as numeric variables. All variables that were originally explicit have been transformed into factors. Each pattern was assigned a numerical value ranging from 1 to 400 without bias. The dataset exhibits a significant number of missing values and a total time range of 158 units. Typically, individuals experiencing symptoms may overlook certain diagnostic measures for various reasons prior to receiving a diagnosis. In situations where the diagnostic categories of samples are unknown, the absence of values may be observed in the data, necessitating the use of an appropriate imputation method.

- K-NN CLASSIFICATION

The K-Nearest Neighbour (K-NN) algorithm is a non-parametric method used for classification and regression in the field of pattern recognition. Each instance comprises the K nearest educational samples within the feature space. The K-Nearest Neighbours (KNN) algorithm is a type of instance-based machine learning approach. The K-NN classification algorithm produces a categorical label as its output. The process of classification is accomplished by means of a consensus among neighbouring data points. In the scenario where K equals 1, the magnificence is determined by the closest neighbour that is not paired with any other. In a common weighting scheme, a neighbour's weight is determined by their distance, where a man or woman's neighbour is assigned a weight of 1/d if d represents the distance to the neighbour. The Euclidean distance, which is defined as a straight line connecting any two neighbouring points, consistently represents the shortest distance between them. The K-Nearest Neighbour algorithm's drawback lies in its sensitivity to the local arrangement of the data. The process of transforming a set of raw data into a reduced set of features is commonly known as feature extraction. The dataset on chronic kidney disease has been sourced from the UCI database and comprises 25 variables and 400 instances. The variables under consideration include non-stop, nominal, and binary types. Therefore, nominal variables such as unique gravity, albumin, and sugar are selected as attributes. The nominal variables are transformed into binary format, and a K-Nearest Neighbours (KNN) algorithm is employed to select appropriate values. In the field of education, a K-nearest neighbours (KNN) algorithm is implemented, and the test set results are presented in the evaluation phase. The primary objective of this algorithm is to evaluate the collective efficacy of ten distance formulae in conjunction with KNN for binary statistics as well as to ascertain the optimal value of k. In this study, a range of values from 175 to 190 was assigned, and the resulting error rates were analysed.

- RANDOM FOREST CLASSIFIER

The Random Forest (RF) algorithm has been suggested as a viable method for addressing persistent kidney disease. This approach is known for its speed, high level of accuracy, and ability to resist noise. The utilisation of bagging and random feature selection techniques exhibits a degree of variability. Each tree within the forest is influenced by the values of randomly sampled vectors and exhibits a uniform distribution comparable to that of every other tree in the forest. Random Forest (RF) is a machine learning algorithm that encompasses a broad range of selection trees. These trees derive their splitting capabilities from the bootstrap training set Si, where I represents the inner node. The growth of trees in random forests (RF) is achieved through the utilisation of the Classification and Regression Tree (CART) methodology without recourse to pruning techniques. As the quantity of timber within a forest increases, the likelihood of generalisation errors also increases until it reaches a certain threshold. Distinctive machine learning techniques were employed for the diagnosis of chronic kidney disease (CKD). The outcomes were depicted using a confusion matrix. The results display the precision, F-degree, and overall classification accuracy measures. As is evident from the tabular data, the most optimal outcomes have been achieved by employing a random forest (RF) classifier. The RF's overall accuracy is assessed for quality using various standard sets of rules. Furthermore, the decision tree classifier was obtained subsequently. The implementation of the K-Nearest Neighbours (K-NN) algorithm with a parameter value of 100 and a normalised polynomial kernel has resulted in successful labelling of higher styles. The accuracy rate of the LR classifier was found to be typical and ordinary.

- ADA BOOST CLASSIFIER

The approach involves the integration of multiple classifiers in order to enhance their accuracy. AdaBoost is an iterative technique for constructing an ensemble of models. The AdaBoost algorithm constructs a robust classifier by amalgamating numerous weak classifiers that exhibit suboptimal performance, resulting in a powerful classifier with high accuracy. The fundamental principle underlying Adaboost is to assign weights to classifiers and iteratively train the data sample to achieve precise predictions of atypical observations. If a machine learning algorithm has the capability to accept weights on the training set, it can serve as a foundational classifier.

Classifier	Precision	Accuracy	Recall	F1-Score
KNN	0.96	0.96	0.92	0.96
RFC	1.00	1.00	1.00	1.00
ABC	1.00	1.00	1.00	1.00

IV. RESULTS AND DISCUSSIONS

The suggested model accuracy was determined by making the CKD class value positive and the not-CKD class value negative. The confusion matrix employed TP, TN, FP, and FN to evaluate performance. TP says CKD samples were accurately categorised. CKD samples were misclassified by the FN test. FP results indicate that non-CKD samples were misidentified. TN samples are correctly classified as CKD-free. Training uses 75% of the dataset, whereas testing and validation utilise 25%.Accuracy: The percentage of accurate forecasts. Predicting outcomes correctly is accuracy.

A. Equations

Accuracy : This refers to the ratio of accurate guesses to total predictions. The capacity to correctly predict a situation's outcome can be used to define accuracy..

$$Accuracy = TP + TN/ TP + TN + FP + FN$$

Recall : The following equation demonstrates how the recall determines the ratio of correctly predicted positive observations to all observations in the class.

$$Recall = TP/ TP + FN$$

Precision : This metric denotes the ratio of correctly predicted positive observations to all positive predictions, as shown in the equation below.

$$Precision = TP/TP + FP$$

F-Measure : The F-measure uses a weighted average of precision and recall. False positive and false negative results are a part in the process.

$$F - Measure = Two \times (Precision \times Recall) / (Precision + Recall) \quad (9)$$

The F-Measure values lie from 0 to 1

B. Comparison of Algorithms

To determine which of the three algorithms provides accuracy of 100 percent, a model comparison is conducted between each of the three algorithms. Whereas the accuracy of the existing systems ranged between 95 point 84 and 66 point 3 percent, our systems' accuracy ranged from 100 percent by random forest and ABC to 96 point 0 percent by KNN.

C. Bar Graph Representation

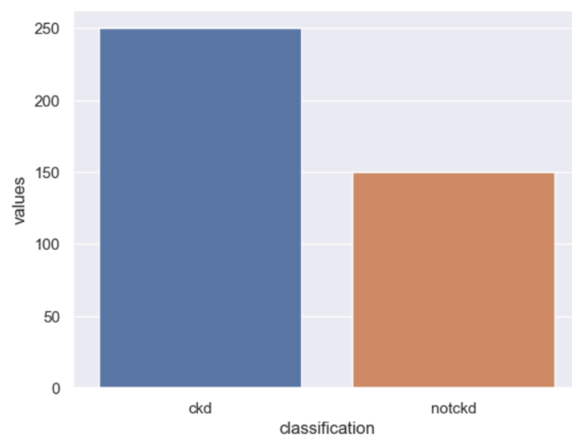

Fig-1: Classification of CKD and Not-CKD

In the above graph we have checked the label imbalance between CKD and Not-CKD

D. Flow Diagram

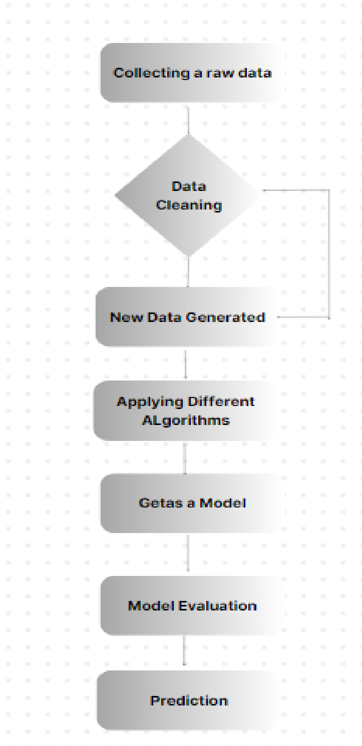

Fig-2: Data Processing

The above flowchart represents how the data processing takes place in algorithms, when the dataset is collected, the data processing step should be taken into consideration to have clean data to train and test the model.

V. CONCLUSION

The timely anticipation of chronic kidney disease's progression to kidney failure is of paramount importance for both healthcare professionals and patients. The present investigation employed three distinct machine learning models, namely KNN, RFC, and ABC, to construct the proposed models. Initially, the triad of machine learning algorithms were implemented on the unaltered datasets, encompassing all 24 features. When utilising the models from the initial dataset, the KNN, RFC, and ABC methods exhibit the greatest degree of accuracy. The binary class achieved a 100% accuracy rate, while the five-class class achieved a 96% accuracy rate. The K-Nearest Neighbours (KNN) algorithm exhibited inferior performance in comparison to the Random Forest Classifier (RFC). The f1_score values obtained from RFC and ABC were the highest, indicating a 100% level of accuracy. Therefore, it is believed that the implementation of multi-classification techniques is of great significance in identifying the various stages of disease and recommending appropriate treatment options to potentially save the lives of patients. The present investigation employed a supervised machine-learning algorithm and feature selection techniques to identify the optimal subset of features for model development. One drawback of the proposed model relates to its limited testing on small datasets. Comparing the efficacy of unsupervised and deep learning algorithms is advisable, and it is recommended that the model be subjected to rigorous testing with a substantial dataset to obtain accurate performance results. The proposed model facilitates prompt decision-making by experts. A mobile-based system is recommended to enhance accessibility for experts to monitor patient status and for patients to access their own status information.

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