DATA-DRIVEN EARLY DIAGNOSIS OF CHRONIC KIDNEY DISEASE: DEVELOPMENT AND EVALUATION OF AN EXPLAINABLE AI MODEL

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ABSTRACT

Chronic Kidney Disease (CKD) is a progressive condition that often remains undetected until advanced stages, leading to severe health complications. Early diagnosis is crucial for timely intervention and improved patient outcomes. This study focuses on developing a data-driven, explainable AI model to facilitate the early detection of CKD. By utilizing machine learning techniques on clinical and laboratory data, the model aims to enhance diagnostic accuracy while maintaining interpretability for healthcare professionals. Feature selection methods are employed to identify key predictors, ensuring that the AI model provides transparent and actionable insights for early disease detection. The developed AI model undergoes rigorous evaluation using real-world datasets to assess its predictive performance and clinical applicability. Explainability techniques such as SHAP (Shapley Additive Explanations) and feature importance analysis are integrated to ensure that model decisions are interpretable and trustworthy. Comparative analysis with existing diagnostic approaches demonstrates the effectiveness of the proposed model in enhancing early CKD detection. The findings suggest that explainable AI can bridge the gap between advanced predictive analytics and clinical decision-making, ultimately supporting healthcare providers in early intervention and personalized treatment strategies.

1. INTRODUCTION

Chronic Kidney Disease (CKD) is a global health concern that affects millions of people worldwide. It is a progressive condition characterized by a gradual loss of kidney function over time, which, if left undiagnosed and untreated, can lead to severe complications such as kidney failure and cardiovascular diseases. CKD is often asymptomatic in its early stages, making timely diagnosis challenging. As a result, many patients remain undiagnosed until the disease has progressed to an advanced stage, at which point treatment options become limited and costly. Traditional diagnostic methods, such as serum creatinine tests and glomerular filtration rate (GFR) estimation, are effective but may not be sufficient for early detection due to their reliance on clinical thresholds that may not reflect subtle disease progression.

1.1 Role of Explainable AI in Healthcare

Explainable AI (XAI) seeks to address this challenge by providing models

that not only make accurate predictions but also explain how and why those predictions were made. XAI techniques, such as Shapley Additive Explanations (SHAP) and feature importance analysis, can highlight the most relevant factors influencing the model's decisions. This transparency allows clinicians to verify the AI's reasoning, increasing trust and facilitating integration into clinical workflows. By ensuring that the model's outputs are interpretable, XAI can bridge the gap between AI-driven insights and clinical decision-making, making AI tools more acceptable and useful in real-world healthcare settings.

1.2 Development of an Explainable AI Model for CKD Diagnosis

The primary objective of this research is to develop a data-driven, explainable AI model for the early diagnosis of CKD. This involves collecting and analyzing clinical and laboratory data, selecting the most relevant features for disease prediction, and implementing machine learning algorithms that balance accuracy with interpretability. The model is designed to process patient data and provide predictions regarding CKD risk while explaining the reasoning behind its decisions.

2. LITERATURE REVIEW

The early diagnosis of chronic kidney disease (CKD) is crucial for preventing its progression and reducing the risk of complications such as kidney failure and cardiovascular diseases. However, traditional diagnostic methods often fail to detect CKD at its initial stages, leading to delayed interventions and poor patient outcomes. Recent advancements in artificial intelligence (AI) and machine learning (ML) have opened new possibilities for improving disease prediction and diagnosis. Additionally, explainable AI (XAI) has emerged as a key area of research to address the interpretability challenges associated with AI models in healthcare.

2.1 Chronic Kidney Disease Diagnosis

CKD is a long-term condition characterized by the gradual loss of kidney function. The disease is classified into different stages based on the estimated glomerular filtration rate (eGFR) and the presence of kidney damage markers such as albuminuria. Traditional diagnostic methods for CKD rely on laboratory tests, including serum creatinine levels, blood urea nitrogen (BUN), and urine analysis.

To address these challenges, researchers have explored alternative biomarkers and predictive models for CKD detection. Studies have investigated the role of novel biomarkers such as cystatin C, neutrophil gelatinase-associated lipocalin (NGAL), and kidney injury molecule-1

(KIM-1) in early disease detection. However, these biomarkers are not widely available in clinical practice, highlighting the need for more accessible and data-driven approaches for CKD diagnosis.

2.2 Machine Learning in CKD Prediction

The application of AI and ML in healthcare has gained significant attention due to its potential to improve disease diagnosis, treatment planning, and patient monitoring. Various ML algorithms have been explored for CKD prediction, including decision trees, support vector machines (SVM), random forests, and deep learning models.

3. PROPOSED SYSTEM

The methodology for this study focuses on the development and evaluation of an explainable artificial intelligence (AI) model for the early diagnosis of chronic kidney disease (CKD). The approach involves data collection, preprocessing, model selection, training, and evaluation, as well as the integration of explainability techniques to enhance model transparency.

The goal is to create a reliable and interpretable AI system that assists healthcare professionals in diagnosing CKD at an early stage, allowing for timely medical intervention. The methodology follows a systematic process to ensure accuracy, fairness, and clinical relevance. By leveraging machine learning (ML) algorithms and explainable AI (XAI) techniques, the study aims to improve the detection of CKD while addressing concerns related to trust and interpretability in AI-based medical diagnostics.

4. RESULTS

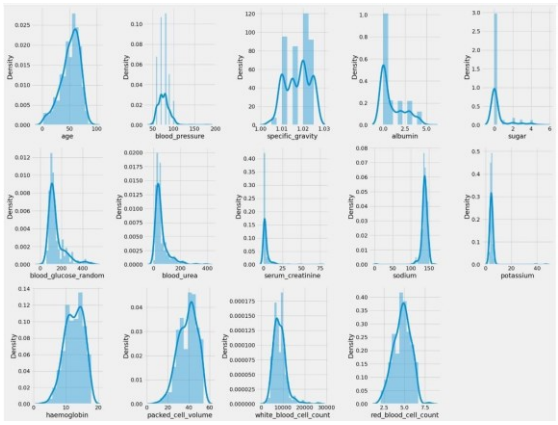

Fig 1: Kernel Density Estimation plots

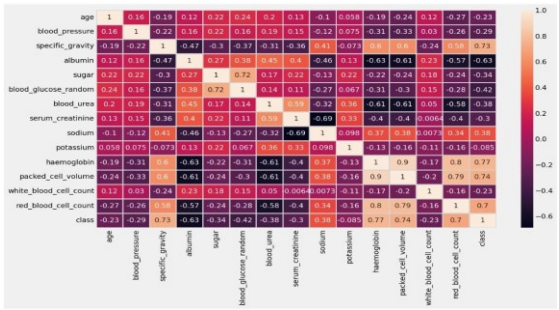

Fig 2: Correlation matrix heatmap

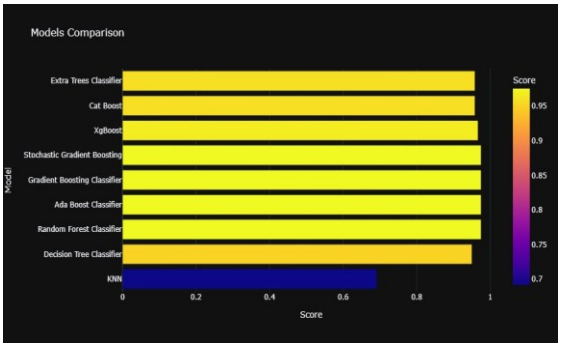

Fig 3: Accuracy graph

CONCLUSION

In conclusion, the proposed AI-driven system for CKD diagnosis represents a transformative approach to early disease detection and management. By combining machine learning, explainability, security, scalability, and continuous improvement, the system enhances medical decision-making and patient care. Its integration with existing healthcare infrastructure ensures broad applicability, making it a valuable tool for hospitals, clinics, and research institutions. As AI continues to evolve, this system sets a foundation for future advancements in predictive healthcare.

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