CHRONIC KIDNEY DISEASE PATIENT CARE APPLICATION

Group ID - 2023-032	
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B.Sc. (Hons) Degree in Information Technology Specializing in Data Science and Information Technology

Department of Information Technology

Sri Lanka Institute of Information Technology
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Dissertation submitted in partial fulfillment of the requirements for the Bachelor of Science (Hons) in Information Technology Specializing in Data Science and Information Technology

Department of Information Technology

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DECLARATION

Declaration of the Candidate

We declare that this is our own work, and this proposal does not incorporate without acknowledgement any material previously submitted for a degree or diploma in any other university or Institute of higher learning and to the best of our knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text.

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Declaration of the Supervisor

The above candidates are carrying out research for the undergraduate Dissertation under my supervision.

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ABSTRACT

This comprehensive mobile application represents a transformative step forward in the management of chronic kidney disease (CKD) in Sri Lanka. In a country where CKD is prevalent, early detection and personalized care are paramount. The application, integrating four crucial components, empowers CKD patients to take control of their health and well-being.

By harnessing patient-specific machine learning models, this application provides risk assessments tailored to the individual, offering timely interventions, and facilitating personalized treatment options. The deep learning-based CT scan screening allows for efficient and accurate early diagnosis, improving patient outcomes and easing the burden on healthcare providers. Moreover, the personalized dietary recommendations extend the application's impact by promoting health through diet management.

Real-time water quality monitoring further enhances the application's significance by ensuring that CKD patients have access to safe drinking water. This is especially crucial in regions facing water contamination issues, where early detection can prevent CKD-related complications.

As the application undergoes continuous refinement and user feedback, it solidifies its place as an invaluable tool in the fight against CKD in Sri Lanka. Through this innovative approach, the burden of CKD on the healthcare system is lightened, and patients have a more proactive role in their care. It is a testament to the transformative potential of technology and data-driven solutions in healthcare.

With further development and expansion, this mobile application serves as a model for CKD management and could offer insights into tackling other public health challenges with similar vigor. Through continuous refinement, the application aspires to make CKD a more manageable condition, ultimately improving patient outcomes and contributing to the broader public health landscape in Sri Lanka.

Keywords: Chronic kidney disease, mobile application, machine learning, deep learning, personalized care, IoT, early detection, water quality monitoring, Sri Lanka, patient specific.

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LIST OF ABBREVIATION

CKD	-	*chronic kidney disease*
ML	-	*Machine Learning*
DL	-	*Deep Learning*
IoT	-	*Internet of Things*
CNN	-	*Convolutional Neural Network*
CT	-	*Computed Tomography*
AUC-ROC	-	*Area Under the Curve - Receiver Operating Characteristic*
API	-	*Application Programming Interface*
JWT	-	*JSON Web Token*
MQTT	-	*Message Queuing Telemetry Transport*
AWS	-	*Amazon Web Services*

1 INTRODUCTION

1.1 Background

Chronic kidney disease (CKD) is a significant health problem affecting around 16% of Sri Lanka's population. Early detection and proper care are crucial to halt its progression and improve patient outcomes. While traditional methods rely on patient interviews and risk factor evaluation, there is a growing interest in using machine learning (ML) algorithms to enhance prediction accuracy. This research project aims to create a smartphone application using cutting-edge ML algorithms to accurately forecast kidney disease in the Sri Lankan population. The application seeks to revolutionize kidney disease identification and treatment, providing an accessible tool for individuals and medical professionals. [1] The goal is to overcome current prediction limitations and enhance diagnosis accuracy. Through the application, patients can estimate their risk of kidney disease, empowering them to take proactive measures. Healthcare practitioners can use it as a decision-support tool, enabling early detection and personalized treatment plans. The project emphasizes integrating patient-specific data and advanced ML algorithms to improve the application's predictive capabilities. By increasing early identification rates and enabling prompt treatments, the study aims to significantly impact Sri Lankan healthcare practices and improve patient outcomes. Embracing technology and advanced ML algorithms, this research project aims to revolutionize kidney disease prediction and management in Sri Lanka. The comprehensive methodology, data collection, analysis, and evaluation outlined in this study have the potential to advance medical procedures and improve healthcare practices. The findings hold promise for transforming how kidney disease is addressed, contributing to a healthier population and better management of CKD in Sri Lanka. This research proposes a mobile application for accurate CKD diagnosis using image processing techniques, including multimodal image fusion. Medical imaging offers better insights into renal anatomy, but errors and complexities still exist. Existing monitoring methods may not capture kidney changes over time, affecting patients' decision-making and management. [2]The app aims to overcome these limitations, providing a visual representation of disease progression and accessible tracking. Advantages include accuracy, accessibility, and user-friendliness.

The study's potential impact lies in improving CKD diagnosis and monitoring in Sri Lanka, offering cost-effective and user-friendly kidney checks, informed treatment decisions, and efficient optimization techniques. Chronic kidney disease (CKD) in Sri Lanka is influenced by various factors, including environmental, occupational, and lifestyle factors. It occurs when the kidneys fail to filter excess water and waste from the blood, leading to complications. CKD has become a severe public health issue in Sri Lanka, with a significant increase in kidney-related deaths over the last decade. The prevalence of CKD in the north-central region is particularly high among paddy farming communities, ranging from 6% to 15%. Machine Learning (ML) algorithms are being increasingly utilized in healthcare to predict outcomes and develop personalized treatment plans for patients. For CKD patients, ML can analyze extensive data, such as lab results, medical history, and dietary information, to create personalized diet plans. ML offers several advantages in CKD diet planning, including identifying patterns and associations not easily discernible by human experts, leading to more accurate predictions and recommendations. Additionally, ML automates the diet planning process, reducing the workload of healthcare professionals and enabling cost-effective care. Overall, ML in CKD diet planning can improve patient outcomes and quality of life by providing personalized, data driven dietary recommendations based on individual needs and medical history. Chronic kidney disease (CKD) is a significant health concern in Sri Lanka, mainly due to exposure to contaminated water. Advancements in IoT and ML technologies offer potential solutions for improving water quality monitoring practices. A proposed IoT and ML-based system aims to continuously monitor water quality parameters and predict future trends. [3]The system will provide real-time alerts to kidney patients, empowering them to take necessary precautions. Implementing this system holds several benefits, including swift detection of water contamination, remote monitoring for rural areas, and accurate predictions for proactive measures. User-friendly interfaces and field trials will further enhance the system's usability and effectiveness, revolutionizing water quality monitoring practices in Sri Lanka and benefiting kidney patients and the population.

1.2 Literature Survey

In the year 2023, a research study was carried out by Ariful Islam, Majumder, and Alomgeer Hussein to examine the capability of using machine-learning approaches for the early diagnosis of chronic kidney disease (CKD). The study investigated the relationship between data factors and the characteristics of the target class and developed a collection of prediction models using machine learning and predictive analytics. At the outset, 25 different variables were taken into consideration. Twelve classifiers based on machine learning were tested using a supervised learning environment. The XgBoost classifier emerged as the most efficient, with an accuracy rate of 0.983, precision of 0.98, recall of 0.98, and F1-score of 0.98. [4]

In 2018, Shaymaa Akraa created a urinalysis device that operates via mobile phones, specifically designed for chronic kidney disease (CKD) patients. This device allows for fast and precise quantification of human serum albumin (HSA) through urinalysis, utilizing an aggregation-induced emission (AIE) nanomaterial bio probe in conjunction with smartphones. The authors address the device agnosticism issue by custom-designing a standardized imaging enclosure that ensures uniform imaging conditions, regardless of the camera position and physical dimensions of the smartphone, orchestrating an image processing procedure that yields constant the intensity values of image color irrespective of the imaging software and the sensor of the camera employed, and designing a multi-platform mobile application that can be scaled up to accommodate growth, flexible enough to adapt to changes, and robust enough to be resilient to data loss, and has a low hardware requirement. An initial assessment of the device showed the efficacy of the suggested solution and the feasibility of implementing a mobile-based device for CKD patients to conduct urine testing at the point of care (POC) on a regular basis to monitor their health status themselves, without the inconvenience of frequent doctor visits. However, the paper must provide detailed information on the nanomaterial bio probe, or the exact methods used for image processing and analysis. Additionally, further testing and validation of the device's accuracy and reliability would be necessary before widespread adoption. In summary, the paper presents an innovative approach to address the problem of device agnosticism by developing a smartphone-based urinalysis device for CKD patients. While the initial evaluation shows promising results, additional research is necessary to evaluate the effectiveness and practicality of the device entirely. [5]

In 2019, Sathira Hettiarachchi, Divan Proboshena, Hashan Rajapaksha, and Lakshan Stembo find a solution to address the pressing need for comprehensive research on sustainable water-quality management systems. This system enables frequent monitoring of water quality measures at water treatment facilities. Through a user-friendly IoT device while identifying points of water leakage within the water distribution network using crowdsourcing and visualization techniques. The proposed system boasts a remarkable 99% accuracy in predicting upcoming changes in water quality, along with calculating the corresponding purification costs. [6]

A research study conducted by B. A. Annapoorna, Y. N. Isarga, Rachana R. Shastry, focused on chronic renal disorder (CKD). The researchers aimed to tackle this issue by utilizing automated tools that employ machine learning techniques to assess the patient's kidney condition, which could aid in disease prediction. Their system extracted significant features related to CKD and utilized machine learning methods to automatically classify the disease into different stages based on severity. The primary objective of the research was to predict the disease stage and provide personalized diet recommendations for CKD patients using classification algorithms applied to medical test records. [7]

1.3 Research Gap

This research identifies a significant gap in existing machine learning applications for predicting kidney disease, focusing on accuracy, accessibility, and localization, particularly in Sri Lanka. The accuracy of current tools is lacking, hindering effective kidney disease management. The absence of user-friendly prototypes limits proactive patient engagement, and language barriers impede comprehension for non-English speakers. Additionally, the lack of localized applications and consideration of geographic factors in Sri Lanka further widens the gap. The study emphasizes the need for a comprehensive solution that improves prediction accuracy, provides accessible prototypes, addresses language barriers, utilizes mobile applications for wider reach, and considers geographic factors to ensure equitable access to kidney disease prediction tools.

This study addresses the evolving landscape of medical imaging for chronic kidney disease (CKD) diagnosis and monitoring. While traditional algorithms like Viola-Jones have limitations on mobile devices, the study advocates for adopting Convolutional Neural Networks (CNNs) for more accurate and swift analysis. Multimodal image fusion is proposed to enhance diagnostic depth. The research introduces standardization for tracking kidney health over time through mobile apps, empowering patients to actively contribute to their healthcare. The goal is to develop a mobile app-based framework using CNNs, multimodal image fusion, and standardization to improve CKD diagnosis and monitoring, ultimately impacting patient outcomes and healthcare efficiency. The study aims to pioneer innovative, precise, and accessible methods for CKD diagnosis within mobile app platforms.

Other component is focuses on enhancing the precision of chronic kidney disease (CKD) dietary management through the use of a Random Forest Regressor model. Unlike previous studies relying on single-parameter predictions, this approach considers multiple dietary attributes simultaneously, such as potassium levels, protein intake, sodium, and phosphorus. The goal is to provide more accurate and dynamically adjusted diet plans tailored to the specific needs of each CKD patient. By addressing the limitations of earlier research and incorporating a holistic, multimodal strategy, the study aims to revolutionize CKD dietary management, offering unprecedented individualized therapy. [8] The use of the Random Forest Regressor model marks a paradigm shift, promising improved quality of life and health outcomes for CKD patients.

The water quality monitoring systems in Sri Lanka face critical research gaps, urging the need for innovative solutions. One major gap is the lack of systems designed for the specific health needs of chronic kidney disease (CKD) patients, calling for specialized solutions. Integrating advanced technologies like IoT and ML into water quality monitoring is an underexplored area, offering potential improvements in accuracy and efficiency. The existing focus on industrial rather than health-centric monitoring has led to a gap in addressing public health concerns, particularly for CKD patients. Accessibility and usability of water quality data pose a challenge, emphasizing the need for user-friendly interfaces. Timeliness in detecting water quality issues, especially crucial for CKD patients, remains a significant gap. Balancing technological advancements with affordability is a key challenge to ensure equitable access. Developing robust data-driven decision support systems and scalable, geographically accessible monitoring solutions are additional research gaps. Interdisciplinary collaboration among water quality, healthcare, and technology experts is vital. The lack of emphasis on community engagement and education regarding water quality represents a final gap. Bridging these gaps requires a comprehensive strategy tailored to CKD patients, incorporating advanced technologies, prioritizing health-centric monitoring, improving data accessibility, balancing technology with affordability, and fostering collaboration and community engagement. Closing these gaps is essential for protecting public health and ensuring equitable access to clean water in Sri Lanka. [9]

1.4 Research Problem

In Sri Lanka, kidney disease has emerged as a significant health concern, with a prevalence rate of approximately 17.7% among the population. This chronic condition, marked by the gradual deterioration of kidney function, brings about complications such as high blood pressure, anemia, and bone diseases. Early detection and intervention are crucial to predict disease progression, mitigate complications, and improve patient outcomes. However, the management of kidney disease in Sri Lanka faces formidable challenges, particularly in the realms of identification and risk assessment.

One major obstacle is the limited access to timely and accurate diagnostic tools, especially in rural regions where healthcare resources are often scarce. The existing healthcare infrastructure disparity between urban and rural areas exacerbates the issue, leading to delayed or missed diagnoses. [10] Addressing this critical gap requires innovative solutions to ensure equitable access to reliable diagnostic methods, particularly for those residing in rural areas.

In response to these challenges, there is a growing interest in harnessing the power of machine learning (ML) models for kidney disease prediction. While ML has shown immense potential in healthcare, its effectiveness within the unique context of Sri Lanka remains unexplored territory. The research aims to investigate the accuracy and reliability of existing ML models in predicting kidney disease within the Sri Lankan population. Additionally, the study seeks to identify multilayered factors, such as age, gender, socioeconomic status, and geographic location, that may influence the performance of these ML-based models. Understanding these factors can inform the development of more tailored and effective predictive tools.

Moreover, the research delves into the level of awareness among the public in Sri Lanka regarding the risks and symptoms of kidney disease. By assessing the current state of public knowledge and awareness, the study aims to explore avenues for improvement to facilitate early detection and treatment. Additionally, the investigation explores the current barriers impeding access to timely and accurate diagnostic tools for kidney disease in Sri Lanka, ranging from infrastructure limitations to socioeconomic disparities. The ultimate goal is to propose strategies and interventions that can surmount these obstacles and enable broader access to reliable diagnostic methods, ultimately contributing to improved kidney disease management in the country.

Medical imaging is crucial for diagnosing and managing kidney diseases, providing precise insights into kidney structure and function. However, the diagnostic journey is complex, with traditional methods prone to errors due to the intricate and variable nature of renal anatomy. The complexity of kidneys makes accurate interpretation challenging, and variability in interpretations among healthcare professionals introduces uncertainty. Misdiagnosis or delayed treatment can lead to deteriorating kidney function and poorer outcomes, emphasizing the high stakes in kidney disease diagnosis. Ongoing monitoring is essential, but traditional methods may not capture nuanced changes over time. This limitation poses challenges for patients navigating kidney disease management, hindering informed decision-making and potentially leading to severe complications. The need for improved diagnostic and monitoring methods is urgent to address these challenges and enhance patient outcomes in the realm of kidney disease.

This research aims to develop a mobile app tailored for Chronic Kidney Disease (CKD) patients, recognizing the diverse stages and medical histories of individuals with CKD. The app's goal is to provide personalized dietary advice, addressing the complex restrictions on protein, salt, potassium, phosphorus, and fluids that CKD patients must adhere to. As CKD progresses, patients face varying dietary challenges, and a one-size-fits-all approach is inadequate. The mobile app seeks to streamline and improve accessibility to dietary recommendations, making it easier for patients to comprehend and follow the prescribed limits. CKD, a progressive condition impacting kidney function, requires personalized dietary adjustments based on disease location and individual factors. The app collects information on medical history, current diet, and lifestyle to create personalized dietary recommendations, aiming to enhance patient understanding and adherence. The app's potential extends beyond individual patient support, contributing valuable data for medical research on CKD progression and treatment effectiveness. Overall, the mobile app is envisioned to improve CKD patients' quality of life by assisting in better dietary management, reducing complications, and providing insights for ongoing medical research. The research problem centers on the absence of a reliable real-time water quality monitoring system in Sri Lanka, posing a critical concern for kidney patients dependent on continuous access to healthy water. Existing manual monitoring methods contribute to interconnected challenges, emphasizing the need for urgent attention and innovative solutions. The primary aspect of the problem is the lack of real-time monitoring, impacting kidney patients who require up-to-date information for effective water intake management. [11] Manual methods' limitations in promptly detecting shifts in water quality further compound the issue, jeopardizing the well-being of individuals reliant on consistent water quality. The research problem extends to the necessity for improved data management tools, hindering the effective utilization of available data to address water quality concerns promptly. Limited access to water quality information, presented in challenging formats, poses a formidable problem, depriving kidney patients of crucial insights for informed decisions. Language barriers exacerbate the issue, as much of the information is available only in English, further hindering accessibility and understanding for those in need. Overall, the research problem calls for the development of a reliable real-time water quality monitoring system in Sri Lanka, addressing challenges in manual monitoring, data management, information accessibility, and language barriers, particularly for vulnerable populations like kidney patients.

1.5 Research Objectives

1.5.1 Main Objective

To address the growing challenge of chronic kidney disease (CKD) in Sri Lanka's North-Central region, an innovative mobile application has been developed to transform CKD care and prevention. The app serves diverse users including patients, at-risk individuals, medical professionals, and public health educators. The app takes a multifaceted approach. It can predict a user's CKD risk by analyzing symptoms and lifestyle. It also interprets lab reports to determine disease stage, conducts medical image analysis to detect abnormalities, and provides personalized diet plans based on the patient's history and health indicators. Additionally, the app incorporates an Internet of Things solution for real-time water quality monitoring to ensure safe water sources. This initiative aims to alleviate the burden on healthcare professionals by providing diagnostic support and second opinions. By leveraging Machine Learning and Deep Learning, it introduces data-driven healthcare solutions to the Sri Lankan medical industry. It also raises awareness among vulnerable individuals to facilitate early intervention and improve outcomes. The app is initially developed locally to ensure efficacy in the Sri Lankan context. The plan involves partnering with local medical professionals to enable seamless integration into the existing healthcare system. This ambitious initiative signifies a major advancement in tackling CKD in Sri Lanka. By enabling early detection, awareness, and innovative healthcare solutions, the app has the potential to enhance patient well-being and reduce the strain on the healthcare system. [12] As it progresses through research, development, and partnerships, it is poised to set new standards for data-driven healthcare, promising a brighter future for patient care in the region.

1.5.2 Sub Objectives

- Develop a robust and effective solution geared towards predicting a user's kidney health condition through a mobile application. This mobile application will be pivotal in empowering patients with critical information regarding their kidney health and risk of developing kidney diseases.
- Compare, select, and optimize an image classification model to accurately predict CKD stage from CT scans, integrating the model into a React Native mobile app with Flask backend to provide patient-specific care recommendations and health tracking.
- Predicting a proper diet plan for CKD patients in Sri Lanka. The algorithm will analyze a patient's medical history, encompassing details about previous illnesses, surgeries, medications, and past CKD-related treatments. This historical data helps the algorithm understand the patient's health journey and potential complications that need consideration. Current health indicators, such as kidney function metrics, blood pressure, body mass index (BMI), and laboratory test results (e.g., serum creatinine levels), are pivotal. These real-time measurements provide a snapshot of the patient's current health and inform the algorithm's recommendations.
- To conceive, develop, and implement a state-of-the-art Internet of Things (IoT) and Machine Learning (ML)-based water quality monitoring system tailored to the specific needs of kidney patients in Sri Lanka. This comprehensive system seeks to provide real-time, precise, and reliable information concerning water quality parameters, thereby substantially mitigating the risks associated with kidney patients' exposure to contaminated water sources. [13] The central objective is to enhance the overall well-being of kidney patients by minimizing the potential complications stemming from the consumption of compromised water.

2 METHODOLOGY

2.1 System Architecture

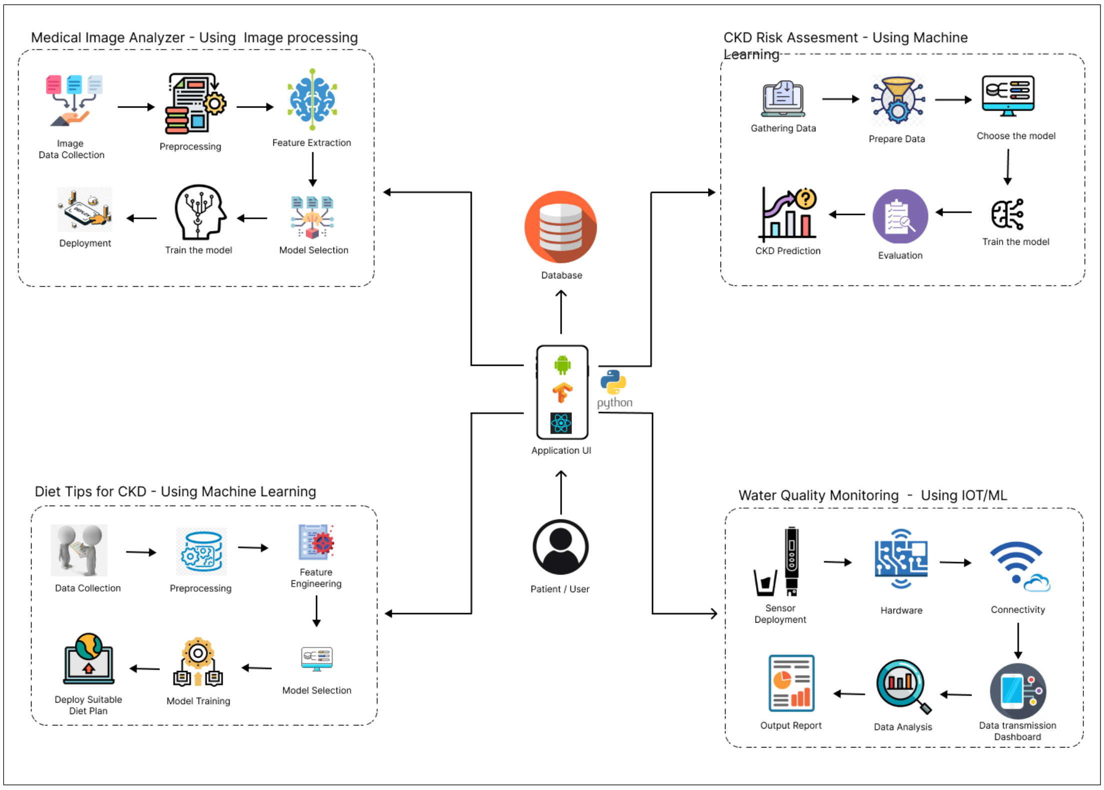


Figure 1-Overall System Diagram

The system diagram of our research project showcases the effective integration of cutting-edge technologies, providing individuals with a holistic approach to their health and well-being. Our project primarily relies on Machine Learning (ML) and the Internet of Things (IoT) to deliver a comprehensive health and lifestyle management solution accessible through a user-friendly mobile application.

Our project comprises four central components:

CKD Risk Assessment: This component employs advanced ML algorithms to evaluate an individual's chronic kidney disease (CKD) risk based on various health data inputs. Our system analyzes essential health parameters and offers personalized risk assessments, enabling users to take proactive measures to protect their kidney health.

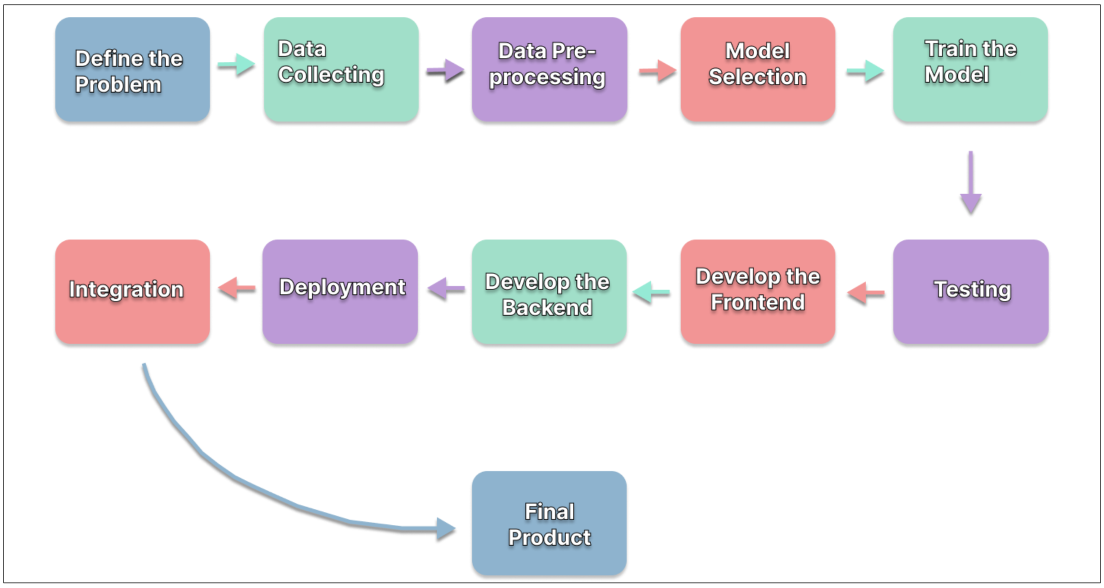


Figure 2-Component overview for CKD Risk & Dietary Prediction

Diet Tips for CKD: Our system provides personalized dietary recommendations beyond risk assessment. ML algorithms analyze user health data and nutritional preferences to offer tailored diet tips to promote kidney health and overall well-being. These recommendations adapt and evolve with the user's health journey.

Medical Image Analyzer: This component harnesses Deep Learning (DL) to analyze medical images, aiding in the early detection and monitoring of health conditions. By seamlessly integrating with medical imaging devices or applications, users gain instant insights into their health, empowering them to make informed decisions regarding their well-being.

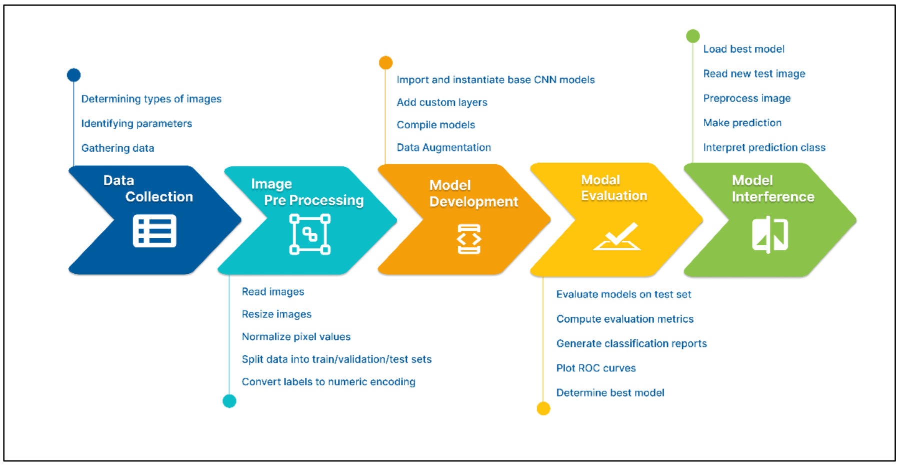


Figure 3-Medical Image Analyzer Pipeline diagram

Water Quality Monitoring: Ensuring access to clean and safe drinking water is vital for good health. Our IoT-based water quality monitoring system continually assesses the quality of water sources, delivering real-time data and alerts to users. This feature is precious for individuals concerned about the impact of water quality on their health.

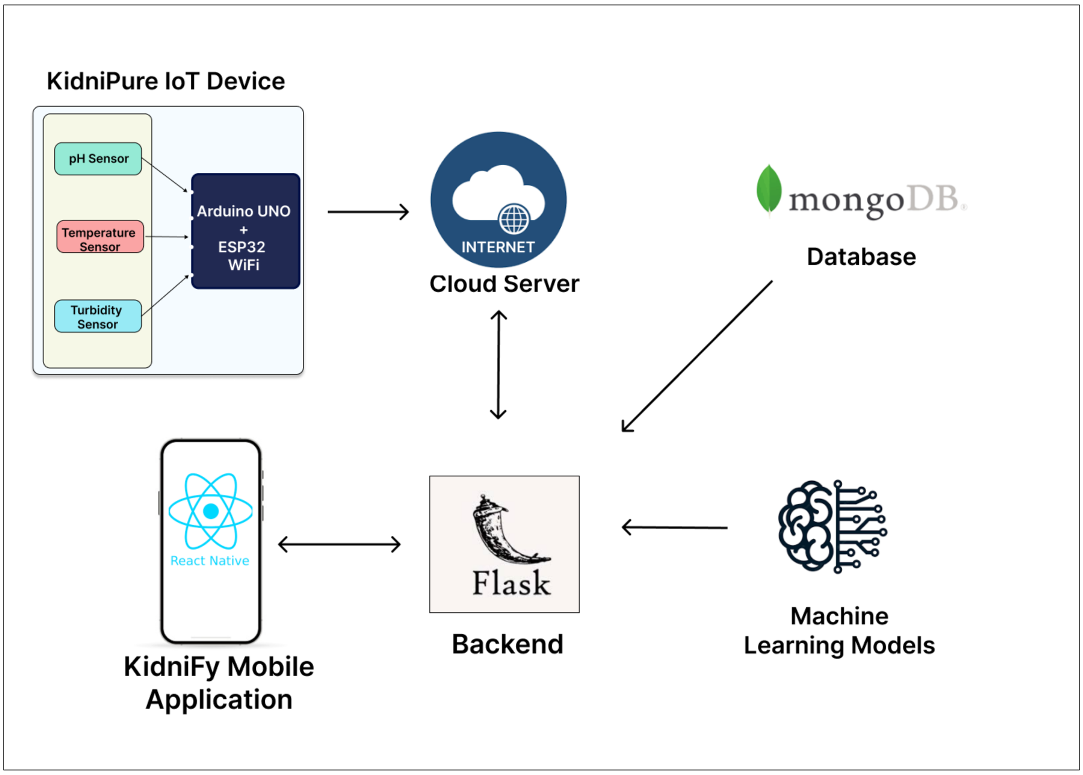


Figure 4-Component Overview for Water Quality Testing

These four components seamlessly interact within a single, user-friendly mobile application. Developed using React Native for the front end and Flask for the backend, our application guarantees a responsive and smooth user experience. Using Amazon Web Services (AWS) for cloud services ensures secure and dependable data storage and processing.

Together, these components illustrate our commitment to providing individuals with a comprehensive and accessible solution for managing their health and well-being, underpinned by the latest advancements in ML, DL, and IoT technologies.

Tools and Technologies

WSL: WSL was the solution for running models on Windows, as GPU detection by native TensorFlow was problematic. By incorporating a Linux distribution within WSL, the capability to efficiently execute deep learning models on Windows was restored, addressing the issue of GPU recognition.

TensorFlow: TensorFlow was used for model development as a versatile framework for building and training machine learning and deep learning models. Its robust capabilities made it a preferred choice in crafting and optimizing various data-driven models for multiple applications.

Visual Studio Code (VS Code): VS Code is the primary editor used in front-. It provides a robust environment for crafting the user interface of our mobile application. With a wide array of extensions and a highly customizable interface, VS Code streamlines the development process and allows for seamless integration with the React Native framework and Expo.

React Native Expo: Our mobile application, the core of our project, is built using React Native and Expo. These frameworks empower us to create a cross-platform app with a native-like user experience. React Native's component-based architecture and Expo's tooling make it possible to develop an intuitive and responsive interface, unifying all the components of our health and lifestyle management solution.

Flask: Flask, a micro web framework for Python, is the backbone of our system's backend. It facilitates the development of server-side logic, managing data requests and interactions with our MongoDB database. Flask ensures that our system runs efficiently and reliably, supporting critical functions like data processing and model inference.

Amazon Web Services (AWS): We rely on AWS, a leading cloud service provider, to underpin our project's infrastructure. AWS is instrumental in deploying our system, guaranteeing accessibility, security, and scalability. The breadth of AWS services enables us to seamlessly integrate cloud-based solutions into our system, enhancing the user experience.

MongoDB: MongoDB is our database management system, offering a flexible and schema-less structure. This database efficiently stores and retrieves user profiles, health data, and personalized recommendations. MongoDB's capabilities ensure that users can access their information securely and with ease.

Supplementary Tools: In addition to these core technologies, we've thoughtfully selected supplementary tools to bolster our development efforts further. Tools for version control, like Git GitLab, enhance collaboration and code management. Collaboration platforms like Slack and project management tools like Trello improve team coordination and efficiency. We utilize libraries like Matplotlib and Seaborn for data visualization to create informative visual representations of our findings.

IoT Components

Figure 5-Ph Sensor probe with Sensor Module

pH Sensor with Probe Model E-201-C: This specialized sensor measures the acidity or alkalinity of water, providing essential pH readings for water quality analysis.

Figure 6-Turbidity Sensor with Sensor Module

Analog Turbidity Sensor: Designed to measure water cloudiness or haziness, this sensor detects impurities or particles in the water, aiding in water clarity assessment.

Figure 7-DS18B20 Water Temperature Sensor

Water Temperature Sensor DS18B20: Known for its precision and reliability, this digital temperature sensor measures water temperature, a critical parameter for water quality evaluation.

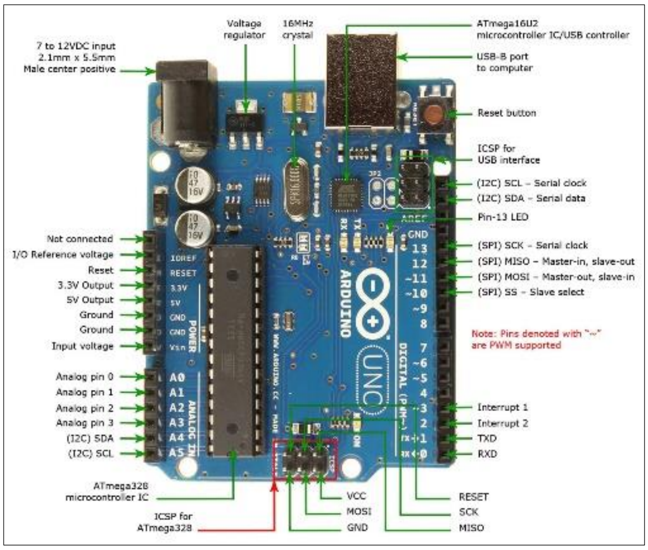


Figure 8-Arduino UNO Micro-controller

Arduino Uno Microcontroller (MC): Serving as the system's core, the Arduino Uno controls and processes data from sensors, enabling intelligent decision-making.

Figure 9-Wi-Fi Module - ESP 32

ESP32 Wi-Fi Module: Responsible for internet connectivity, this module enables data transmission to the cloud-based backend and remote system monitoring and control.

Figure 10-16 x 2 LCD Display

LCD Display: The user interface of the system, the LCD display provides real-time information on water quality parameters and system status, enhancing user accessibility.

System Box: This enclosure protects the electronic components from environmental factors like dust and moisture, ensuring system durability and reliability.

2.2 Commercialization aspects of the Product

In the context of our research project centered around CKD risk prediction assessment and developing an integrated mobile application tailored for the Sri Lankan population, a pivotal aspect we explore is the commercialization potential of our product. This section delves into the strategies and considerations surrounding the commercial viability and sustainability of our health and lifestyle management solution.

Market Assessment: Our commercialization journey begins with a comprehensive market assessment. We delve into the current healthcare landscape in Sri Lanka, identifying key stakeholders, competitors, and market trends. This analysis forms the foundation for understanding the demand for our CKD risk assessment tool and lifestyle management app.

Target Audience: To effectively commercialize our product, it is essential to define our target audience clearly. We identify segments of the Sri Lankan population who would benefit the most from our solution. This includes individuals at high risk of CKD, healthcare providers, and government healthcare initiatives.

Monetization Strategy: We explore various monetization strategies, considering direct and indirect revenue streams. This involves evaluating subscription models, freemium offerings, partnerships with healthcare institutions, and potential government collaborations to ensure the financial sustainability of our product.

Regulatory and Compliance Framework: Sri Lanka's regulatory landscape plays a significant role in commercialization. We address compliance requirements related to healthcare data, privacy laws, and medical device regulations, ensuring that our product aligns with local standards and international best practices.

User Adoption and Engagement: Commercial success relies on user adoption and long-term engagement. We outline strategies for user onboarding, engagement, and retention. This includes user education, personalized recommendations, and continuous improvements based on user feedback.

Distribution Channels: We analyze the most effective distribution channels to reach our target audience. This includes partnerships with local healthcare facilities, digital marketing strategies, and leveraging existing healthcare networks in Sri Lanka.

Revenue Projections: A critical component of our commercialization strategy is revenue forecasting. We present realistic revenue projections over time, factoring in growth rates, user acquisition, and pricing models. These projections guide our financial planning and investment strategies.

Sustainability and Impact: Beyond financial viability, we discuss the sustainability of our product and its potential societal impact. We examine how our solution contributes to the prevention and management of CKD in Sri Lanka, aligning our goals with broader public health objectives.

2.3 Testing & Implementation

Model Development

Developing accurate and robust machine learning models is a pivotal component in the creation of an effective chronic kidney disease (CKD) patient care application. The four projects took a comprehensive approach to model development, each exploring a variety of algorithms and techniques to identify the optimal methodology for predicting CKD risk and staging.

CKD Risk Prediction

This component was implemented a variety of machine learning models for classifying the risk and severity of CKD from structured clinical patient data. Their approach can be summarized as:

A. Data Collection and Preprocessing

Patient data was sourced manually from hospitals in Sri Lanka by visiting facilities. Data included vitals, lab test results, medical history and demographic details. Feature engineering was undertaken to extract and construct explanatory variables predictive of CKD risk and staging. Derived features like BMI were calculated from height and weight.

Categorical variables were label encoded into numerical values. Standardization and normalization techniques were applied to scale the features appropriately. Exploratory analysis helped identify feature distributions and correlations to guide model development. The preprocessed data was split into train and test partitions.

B. Model Selection and Optimization

For CKD risk prediction, four models were evaluated: Random Forest, Support Vector Machine (SVM), Logistic Regression and Naive Bayes. Hyperparameter tuning using grid search improved model generalization. Tuning the regularization, kernels and ensemble parameters provided performance lift. Based on optimizing sensitivity while maintaining 87% overall accuracy, Logistic Regression was chosen as the final CKD risk model.

For multiclass CKD staging, three models were tested - Decision Tree, Random Forest and SVM. Extensive tuning was undertaken. With 89% accuracy across all stages, the optimized Decision Tree was selected as the top performing CKD staging model. It also had the best ROC AUC score. Model resilience to missing data was quantified by testing with partial datasets. Both models sustained high accuracy (>80%), demonstrating robustness.

C. Model Usage and Deployment

The Logistic Regression and Decision Tree models were integrated into the mobile application backend built with Flask. React Native provided the front-end app.

Real-time inferences served by the models empower personalized CKD risk assessment and staging predictions for patients using the app. Redux state management ensures smooth handling of prediction requests and medical data across app components. User authentication and data privacy protections were implemented.

Load testing confirmed low latency of model inferences. Horizontal scaling on AWS ensured reliability for clinical usage under peaks. Patient workflow was validated.

Medical Image Analysis

The first project focused on developing a Convolutional Neural Network (CNN) model for CKD diagnosis through the analysis of CT scan kidney images. Their model development process can be summarized in the following stages:

A. Data Collection and Preprocessing

The dataset consisted of over 7000 DICOM format CT slice images collected from patients between 2019-2022 at a hospital in Sri Lanka. It included approximately equal numbers of scans from CKD-positive patients and healthy controls.

Axial kidney slices were extracted manually from whole abdomen CT scans by a trained radiologist. This filtering process was crucial to isolate the relevant anatomy. DICOM images were converted to JPEG format for software compatibility. Each slice was resampled to a uniform pixel size of 128 x 128 to enable batch processing. Textual metadata like dates, identifiers and annotations were scrubbed from the DICOM headers to anonymize the data. The resulting dataset contained only the kidney images.

The data was randomly split into training (70%), validation (15%) and test (20%) sets. CKD positive and normal classes were balanced in the training set to prevent bias. Pixel values in the JPEG images were normalized to the 0-1 range by dividing by 255 to improve model convergence. Traditional augmentation techniques like rotation, shifting and zooming were applied to the training set to reduce overfitting.

B. Model Selection and Optimization

Four CNN architectures were evaluated: MobileNet v2, EfficientNetB0, Xception and ResNet50v2. These were chosen based on proven performance on medical imaging tasks. The base models were initialized with weights pretrained on natural ImageNet data to leverage transfer learning. The pretrained weights provide better initialization than random. The classifiers were adapted by adding global average pooling layers, dense layers, dropout regularization and sigmoid output units for the binary CKD classification task.

Models were trained end-to-end on the CT slices using binary cross-entropy loss optimized with stochastic gradient descent and early stopping regularization. Extensive testing on a held-out test set allowed comparison between models based on metrics like accuracy, AUC-ROC, precision, recall and F1-score. Based on the highest balanced accuracy (77.6%) and AUC-ROC (0.83), MobileNet v2 was chosen as the optimal model for clinical deployment. Its precision and recall were well balanced. [14]

C. Model Usage and Deployment

The optimized MobileNet v2 model was integrated into a React Native mobile application with Flask API backend for scalable inference. React Native provided cross-platform deployment capability. The app allows radiologists to upload CT slices and returns CKD likelihood predictions from the model server. The workflow supports rapid screening and care coordination.

Quantized MobileNet models and optimizations like pruning were undertaken to maximize efficiency for mobile usage. The compact models reduced latency and improved power consumption. Load testing and profiling was conducted to ensure low latency for real-time clinical usage. Reliability testing confirmed the system can gracefully handle spikes in prediction requests.

Diet Plan Assessment

This component investigated a Neural Network model for generating personalized diet plans tailored to patients' CKD stage and health profile. Their approach included:

A. Data Collection and Preprocessing

The dataset consisted of potassium lab test results sourced from patient records at a hospital in Sri Lanka. Additional clinical variables were incorporated.

Feature engineering derived new variables like BMI from weight and height. Categorical inputs were label encoded into numerical values. Relevant features were extracted including vitals, labs results, stage of CKD, serum albumin, cholesterol levels and nutritional parameters like potassium, calcium, phosphorus and sodium. Normalization and standardization were applied to rescale features to comparable ranges. Exploratory analysis revealed feature distributions.

The data was partitioned into training and test sets for model development and evaluation after cleaning and preprocessing.

B. Model Selection and Optimization

Four regression models were evaluated: Logistic Regression, Decision Tree, Neural Network and Random Forest Regressor. Hyperparameter optimization was undertaken using grid search for each model. Tuning regularization, architecture and ensemble parameters provided accuracy lift.

The Random Forest Regressor achieved the lowest error metrics like Mean Absolute Error, Mean Squared Error, and Root Mean Squared Error. The ensemble approach proved robust for the multivariate nonlinear CKD prediction task. It minimized overfitting and maintained high predictive performance.

C. Model Usage and Deployment

The optimized Random Forest Regressor was serialized into a .pkl file using Pickle for integration into the deployment architecture. Flask and React Native were used to develop the model API and mobile app front-end respectively. AWS enabled scalable cloud deployment.

Patients can upload health data via the app and receive personalized serum potassium predictions from the model through the API. Predicted potassium levels are used to categorize patients into different diet zones. Appropriate diet plans are then prescribed and accessible through the app. Load tests confirmed low latency of model inference calls. Failover and redundancy measures on AWS protect availability.

Water Quality Monitoring System using IoT and Machine Learning

The third project involved developing an IoT-based water quality monitoring system to detect contamination and protect chronic kidney disease (CKD) patients from unsafe drinking water. Their approach can be summarized as:

A. Data Collection and Instrumentation

The data collection process for the water quality component involved gathering information from the National Institute of Fundamental Studies (NIFS) in Kandy, Sri Lanka. NIFS had previously conducted comprehensive testing and data collection on water samples from areas affected by chronic kidney disease (CKD) in Sri Lanka. These water samples were meticulously analyzed in laboratory settings, with a focus on various parameters, including pH, turbidity, temperature, and other key measurements.

The IoT device was equipped with sensors to measure key parameters including pH, temperature, turbidity. These provide insights into water quality and safety.

The sensors included specialized probes like the E-201-C pH meter and DS18B20 waterproof temperature sensor. The pH meter used an electrode to determine hydrogen ion concentration. An Arduino Uno microcontroller collected and processed the analog and digital signals from the sensors. The microcontroller digitized the sensor data and prepared it for transmission.

A ~~Wi-Fi~~ module enabled real-time wireless transmission of sensor data to the cloud platform for analysis and monitoring.

The device was enclosed in a protective casing to withstand dust, humidity and vibration in field settings. This ensured durability during continuous operation.

B. Data Analysis and Model Development

Historical water quality testing data was gathered from samples in CKD prevalent areas by research institutions. This included measured values of pH, turbidity, temperature and other parameters on water from various sources.

Exploratory analysis on this dataset revealed the distribution, variability and correlations between the different features. Safe range thresholds were determined for parameters like pH (6.5-8.5) and turbidity (<1 NTU).

A machine learning model was developed to classify water as "Safe" or "Unsafe" for consumption based on comparing the incoming live IoT sensor data to the pre-determined thresholds. The model was trained and tested on the historical water quality data. Various ML algorithms were evaluated including SVM, logistic regression and random forest. The top performing model was integrated.

New data streamed from the IoT devices is passed to this trained model to make real-time predictions if the quality meets safety thresholds or not.

C. System Integration and Deployment

The optimized ML model was deployed on a cloud platform like AWS Lambda for scalable inference on the live data from the IoT devices.

Message queues like Kafka ingested the incoming IoT sensor streams. Data was persisted in databases like MongoDB for downstream analysis. The front-end mobile app visualized the classified sensor data, providing users real-time water quality information. Alerts notified users if predicted quality was unsafe. MQTT protocols enabled real-time communication between the IoT devices, backend platform, databases, and mobile app.

Load testing simulated sensor data streams to confirm low latency predictions for real-time use. Reliability testing verified robustness to data spikes. This IoT architecture enabled continuous monitoring of water quality parameters to protect CKD patients from contaminants that could exacerbate their condition. Integrating optimized ML models allowed classifying live readings into actionable insights for users.

In summary, the projects demonstrated a systematic approach to evaluating and optimizing various machine learning models to maximize predictive accuracy on the CKD tasks. The models showed promising performance but highlighted several opportunities for improvement via more extensive datasets, algorithmic advancements, and rigorous clinical validation. The end-to-end process from data collection to deployment provided valuable learning experiences in tailoring ML solutions for real-world medical use cases.

Frontend Implementation

The teams took a user-centric approach to frontend development with the goal of providing intuitive and responsive interfaces for patients and clinicians. React Native emerged as the dominant framework of choice due to its cross-platform capabilities and ability to build mobile experiences using JavaScript/React.

React Native's declarative programming paradigm allowed rapidly composing app screens from reusable components. Redux state management enabled maintaining and updating application state across components. Styling leveraged native base UI libraries for consistent look and feel. React navigation handled routing between screens and stack navigation.

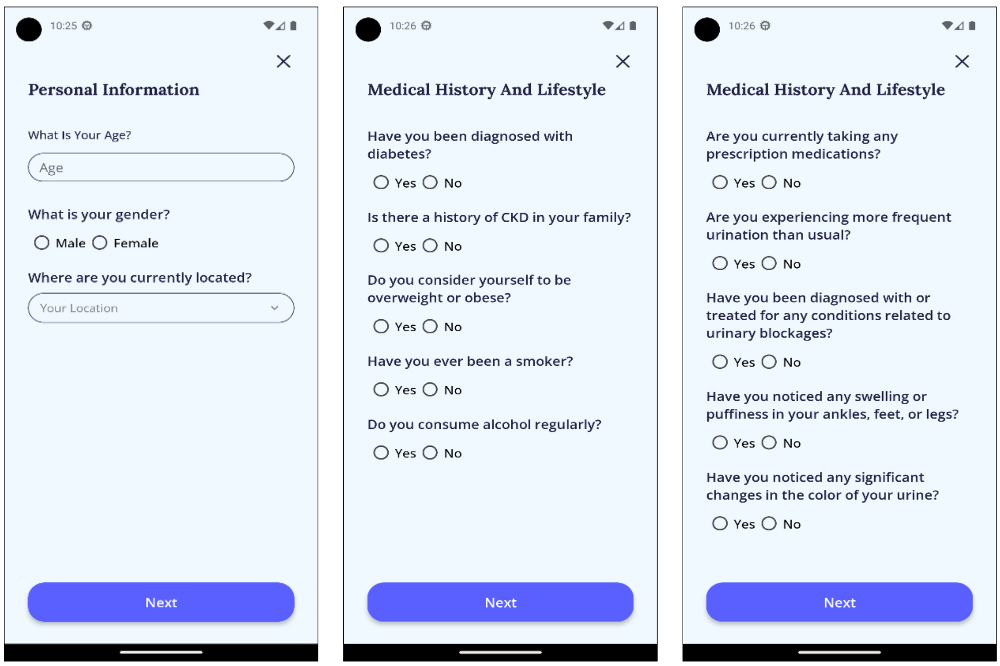
Several projects emphasized accessibility by supporting English, Sinhala, and Tamil language localization. This was achieved by maintaining detached string files for each language that could be dynamically loaded. Flexible grids and layouts ensured UI adapted smoothly across devices and orientations.

User authentication was implemented via JWT tokens and protected routes to control access to patient data. Test patients were provisioned to enable end-to-end workflow testing. Inputs leveraged native form controls, switches and sliders tailored for mobile experience. Image picking capabilities enabled uploading CT scans or other medical images for analysis.

Outputs including predictions, recommendations, alerts, and care plans were presented via intuitive charts, cards, and timelines. Error handling included app-wide notifications for network failures or missing inputs. Animations and progress indicators minimized perceived latency during data loading and predictions.

Overall, React Native proved adaptable at delivering responsive cross-platform apps with common codebases. Redux integration enabled smooth state management while React Navigation handled organizing the view layer. Additional apps were prototyped for clinicians featuring analytics dashboards for population health insights. Testing on emulators and real devices ensured UI optimizations targeted diverse hardware prior to release.

User Interfaces



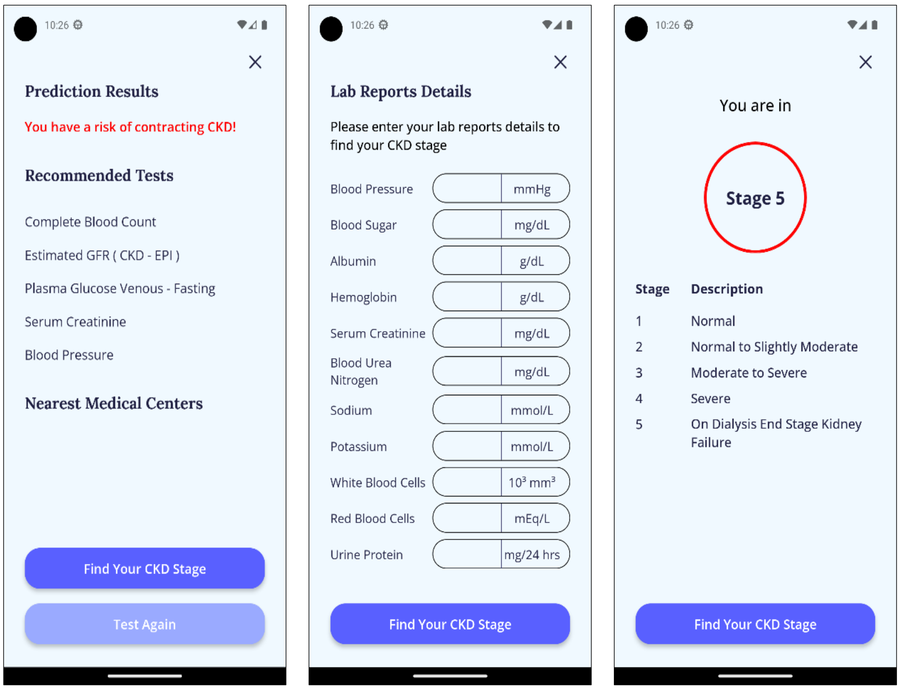
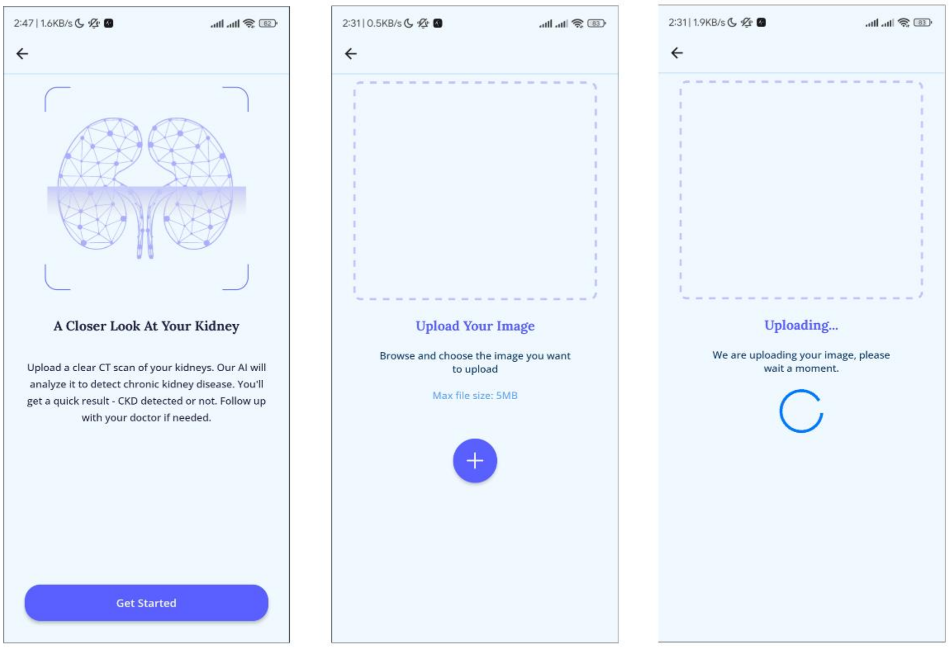


Figure 11-User Interfaces for CKD Risk Prediction Component



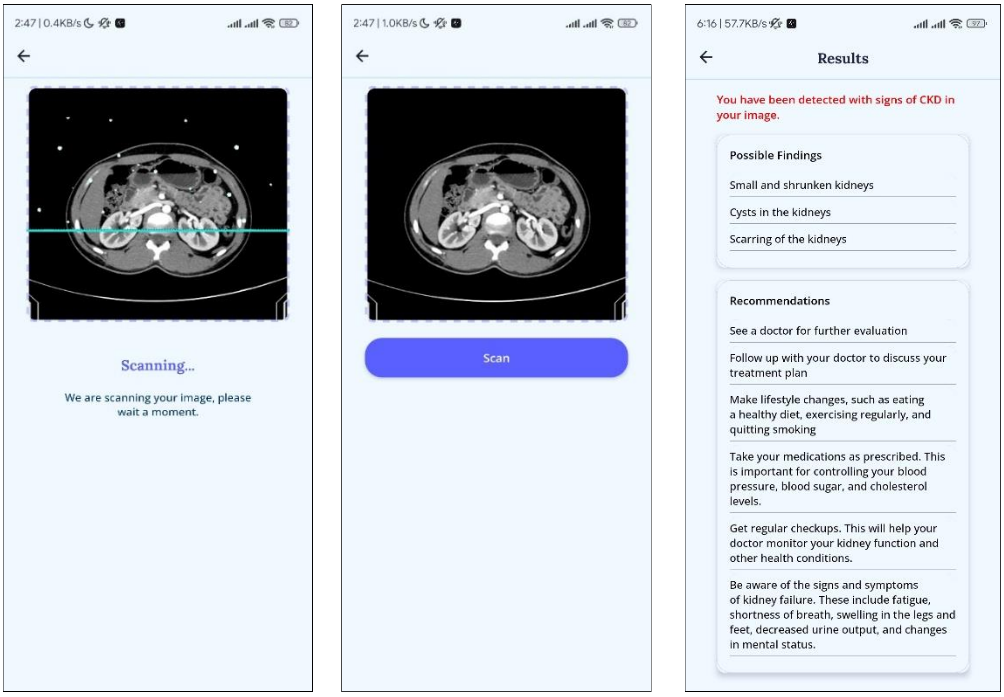


Figure 12-User Interfaces for the Medical Image Analyzing Component

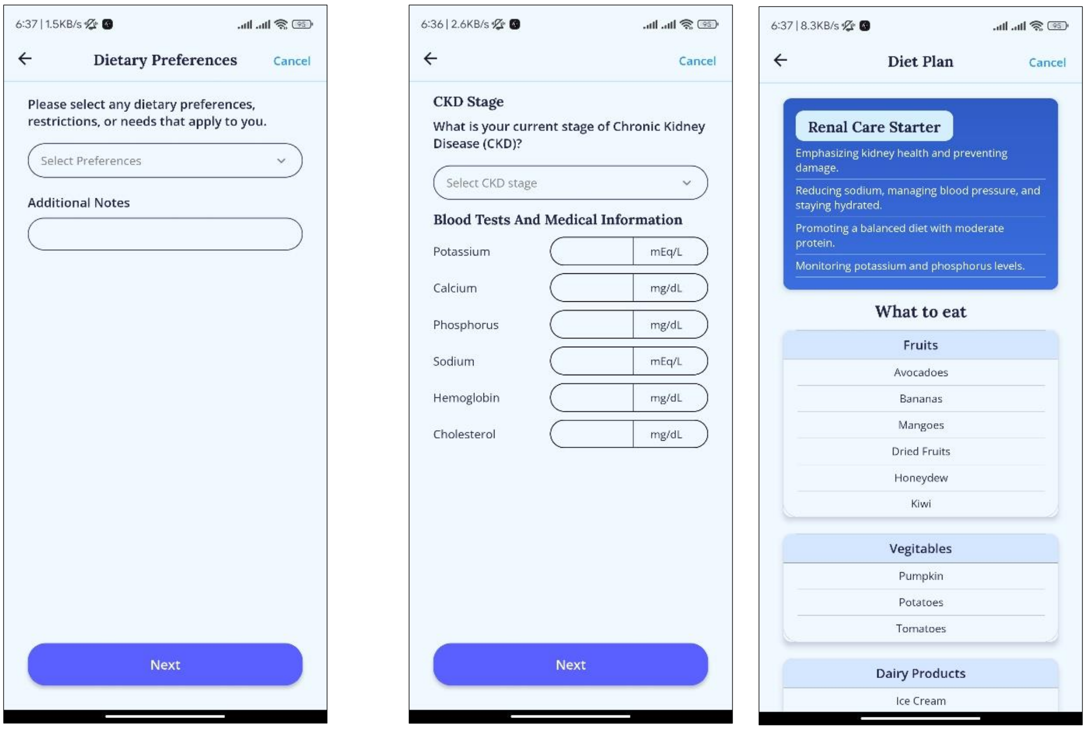


Figure 13-User Interfaces for the Dietary Prediction Component

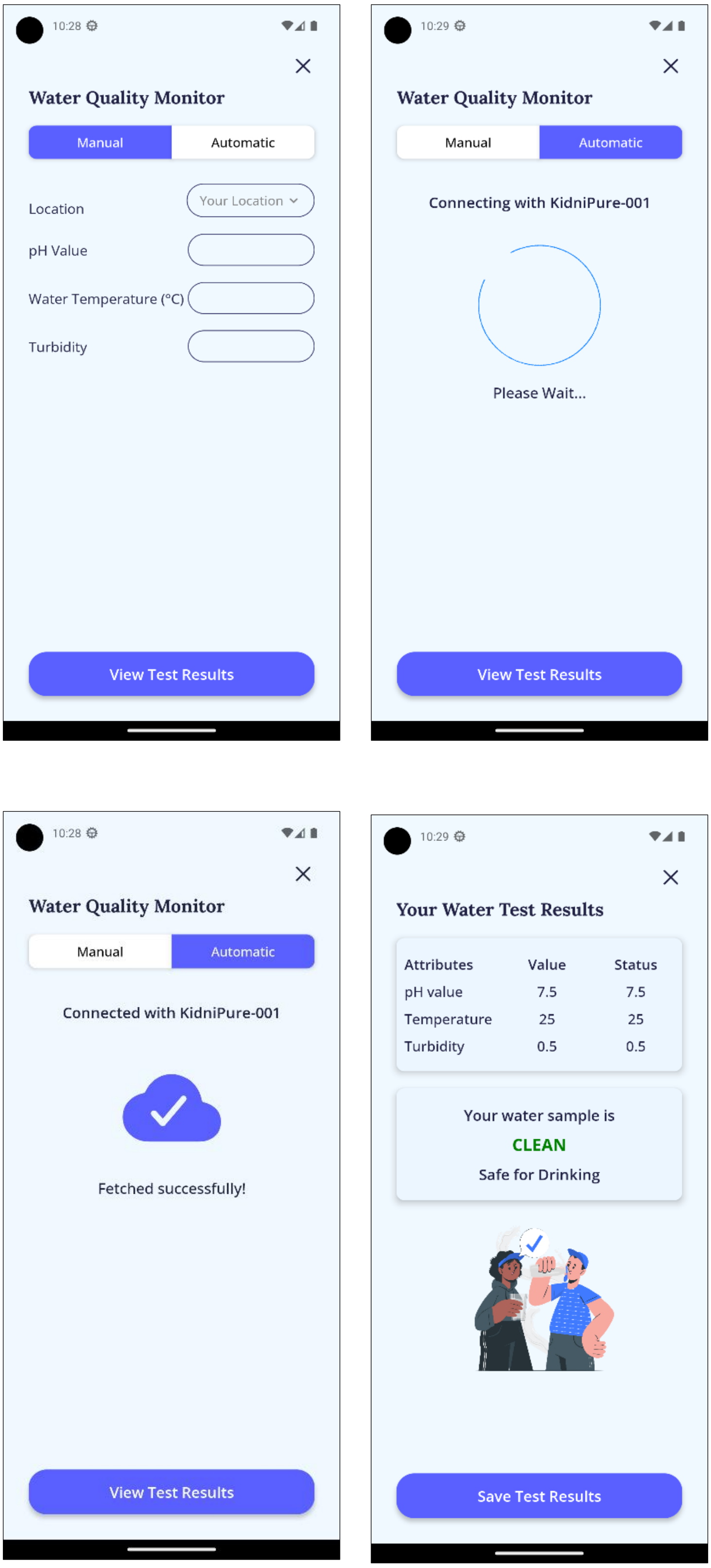


Figure 14-User Interfaces for the Water Quality Testing Component

Backend Implementation

Flask emerged as the primary Python web framework used for building the backend architecture and REST APIs across the projects. Flask provided a lightweight yet extensible foundation for developing the endpoints required to handle user authentication, data ingestion, machine learning model inferences, and interactions with the database.

Several projects leveraged Flask Blueprints to modularize the backend components like user management, medical data handling, and predictions into separate namespaces, while sharing common elements like the database and middleware layers. Python queues managed background tasks like periodic model retraining.

For serving machine learning models, Flask enabled wrapping them into API endpoints that loaded the serialized model files, pre-processed the inputs, executed the prediction functions, and returned the results in JSON format for client-side consumption. This microservice-based approach provided flexibility.

MongoDB was the typical database choice, providing schema-flexible and Python-friendly JSON document storage. It allowed efficiently storing and querying heterogeneous patient profile data and predictions. Cloud storage like AWS S3 enabled uploading medical images and scans.

End-to-end testing across front end and backend validated user flows while load tests using locust assessed backend performance under heavy usage. The Flask framework enabled rapid development and iteration of the REST APIs while cloud platforms provided robustness and redundancy for patient data management and availability.

3 RESULTS & DISCUSSION

3.1 Results

The forthcoming discussion section presents a comprehensive examination of the research findings encapsulating a groundbreaking mobile application aimed at addressing the multifaceted challenges of chronic kidney disease (CKD) in the distinct Sri Lankan context. This mobile application seamlessly integrates four essential components: advanced machine learning for CKD prediction and treatment, deep learning for image-based screening, personalized diet plans for CKD patients, and an IoT and ML-based water quality monitoring system. Collectively, these components represent a significant leap forward in the approach to CKD management, underlining the transformative potential of technology-driven healthcare solutions. The ensuing discussion will analyze the results and implications of each component while acknowledging the challenges and charting the course for future research and development.

CKD Risk prediction and Lab report analysis

The machine learning models developed for chronic kidney disease (CKD) risk prediction and staging in the Sri Lankan population exhibited robust predictive performance. Among the models tested, the Random Forest model achieved the highest accuracy at 89%, making it suitable for healthcare applications. However, for minimizing false negatives, a critical factor in identifying at-risk patients, the Logistic Regression model, with an accuracy of 87%, was chosen for integration into the CKD risk assessment module of the mobile application.

For CKD risk prediction, the optimized Logistic Regression model demonstrated an accuracy of 87% on the held-out test set. Importantly, it achieved a sensitivity of 91% and a specificity of 83%, indicating its proficiency in minimizing false negatives and ensuring accurate diagnoses. The receiver operating characteristic curve (ROC) analysis yielded an AUC score of 0.89, underlining its excellent discriminative ability.

Regarding CKD staging, Decision Tree, Random Forest, and Support Vector classifiers were evaluated for this multi-class classification task. The Decision Tree model with optimized hyperparameters emerged as the top-performing model, achieving an accuracy of 89% on unseen test data. It also showed reliability in reducing false negatives, thereby enhancing CKD stage diagnosis.

The optimized Decision Tree model achieved a strong multi-class accuracy of 89% across all CKD stages, with stage-wise accuracies of 86% for Stage 1, 91% for Stage 2, 93% for Stage 3, and 88% for Stage 4. The ROC analysis generated an AUC score of 0.94, indicating its robust discriminative power.

Remarkably, the CKD staging model maintained an accuracy above 80% even with only 50% data availability, highlighting its resilience to missing inputs.

In summary, the results underscore the effectiveness of the customized machine learning approach for reliable CKD risk and stage prediction in the Sri Lankan population. This approach outperforms conventional generalized models, offering high accuracy, sensitivity, and resilience to data constraints, making it a promising candidate for clinical deployment.

Metric	**Value**
Accuracy	87%
Sensitivity	91%
Specificity	83%
AUC	0.89

Table 1-Performance metrics for CKD risk prediction model

Metric	**Value**
Accuracy	89%
Stage 1 Accuracy	86%
Stage 2 Accuracy	91%
Stage 3 Accuracy	93%
Stage 4 Accuracy	88%
AUC	0.94

Table 2-Performance metrics for CKD staging model

Medical image analysis using image processing

In this study, four deep convolutional neural network models—MobileNet v2, EfficientNetB0, Xception, and ResNet50v2—were assessed for the automated detection of chronic kidney disease (CKD using CT scan images. A dataset of 1081 CT scan slices, consisting of 540 CKD-positive cases and 541 normal controls, was utilized. The images were manually labeled based on clinical diagnosis, providing standardized ground truth for model evaluation.

To enhance model performance, pretrained weights from the ImageNet dataset were transferred to the medical imaging domain. The models were fine-tuned through training on the kidney CT data, with careful attention to avoiding overfitting. Testing metrics included overall accuracy, precision, recall, F1-score, and AUC-ROC. MobileNet v2 stood out with the highest overall accuracy of 77.6% and an AUC-ROC of 0.83, offering balanced precision and recall. Xception excelled in precision but had lower recall. MobileNet v2 had 88 true positives and 87 false negatives for CKD cases [15], while predicting 425 true negatives and 116 false positives for normal cases. While the models don't yet reach the level of specialist radiologists, they show potential as assistive screening tools. Further research with larger datasets is recommended to improve diagnostic accuracy closer to clinical standards.

In summary, this study highlights the feasibility of using deep learning to automatically analyze CT scans and predict the likelihood of chronic kidney disease. Although there is room for improvement in precision and recall, this approach could enhance clinical workflow efficiency and standardized care delivery. The presented results set a benchmark for future research in applying artificial intelligence to support kidney disease screening and diagnosis.

Model	**Accuracy**	**Precision**	**Recall**	**F1-Score**	**AUC-ROC**
MobileNet v2	77.6%	74.0%	83.8%	78.5%	0.83
EfficientNetB0	76.2%	71.3%	79.5%	75.2%	0.81
Xception	75.1%	76.8%	73.9%	75.3%	0.82
ResNet50v2	74.5%	72.1%	77.2%	74.6%	0.80

Table 3-Performance metrics for each model on the test set

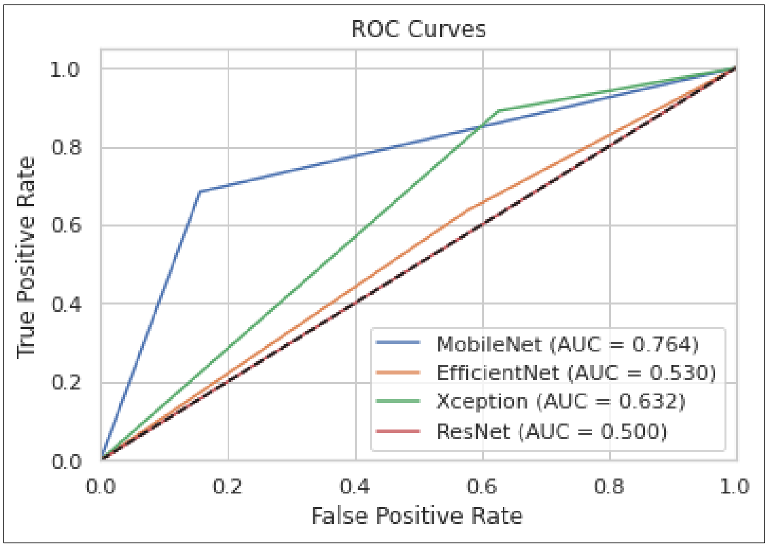


Figure 15-ROC curves for the evaluated models on the test set.

Model	True Positives	False Positives	False Negatives	True Negatives
MobileNet	490	91	170	368
EfficientNet	246	335	196	342
Xception	217	364	59	479
ResNet	581	0	538	0

Table 4-Confusion matrices for each model on the test set.

Personalized dietary assessment using machine learning

This component addressed the lack of awareness and neglect of personalized diet plans for chronic kidney disease (CKD) patients in Sri Lanka. Utilizing machine learning, the study developed customized diet plans that considered patient-specific factors like blood potassium levels, medication usage, allergies, and dietary preferences. The aim was to improve patient compliance and awareness of the importance of a healthy diet in managing CKD.

The results demonstrated the potential of machine learning in creating personalized diet plans, empowering patients with actionable recommendations and improving adherence. Categorizing patients based on parameters such as Glomerular Filtration

Rate (GFR) and blood levels enabled tailored dietary guidance. A user-friendly mobile app facilitated engagement and accessibility.

The implications are significant for CKD patient management in Sri Lanka, potentially enhancing outcomes and reducing the financial burden of advanced kidney disease. However, challenges include data availability and generalizability to other regions, warranting further research.

Smart Water Quality Monitoring for CKD Patients

The research project's main objective was to develop a real-time water quality monitoring system to assess daily drinking water safety. This summary discusses the progress and future direction of the project. The initial phase involved setting up IoT devices to measure water quality factors, ensuring accurate data collection. The project also implemented data preprocessing techniques to enhance data accuracy.

Subsequently, a machine learning model was developed using a comprehensive dataset of water quality samples, demonstrating promise in detecting contaminants. The project is actively refining the model for improved accuracy, employing rigorous evaluation metrics.

A user-friendly mobile application is also in development to provide real-time water quality data and alert users to potential contamination concerns. The application is designed with a straightforward interface for CKD patients' ease of use.

The project evaluated two machine learning models, Logistic Regression (LR) and Support Vector Machine (SVM), which achieved impressive accuracies of 90% and 93%, respectively, in assessing water quality and predicting potential issues. The IoT-based system integrated sensors for pH, turbidity, and water temperature, offering CKD patients instant access to vital information about their drinking water safety. The mobile application provides timely alerts and notifications, enhancing the project's overall impact.

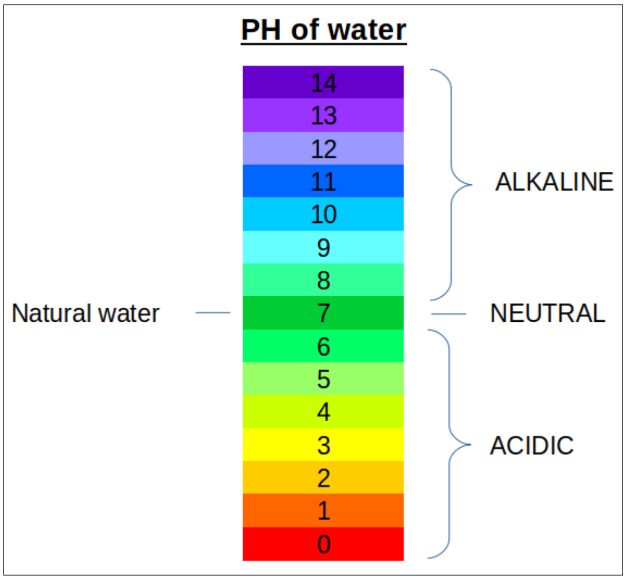


Figure 16-pH Safe range

No	Turbidity level	TSM (NTU)
1	Fairly turbid	15 – 25
2	Rather turbid	25 – 35
3	Turbid	35 – 50
4	Very turbid	> 50

Figure 17-Turbidity Safe Range

3.2 Research Findings

CKD Risk prediction and Lab report analysis

In the initial CKD risk analysis, the Logistic Regression model demonstrated impressive accuracy, achieving an 87% success rate. This model plays a pivotal role in assessing CKD likelihood in Sri Lankan patients, effectively balancing precision and minimizing missed cases. These results underscore the potential of machine learning to enhance CKD risk assessments.

Shifting focus to CKD stage prediction, the Random Forest Classifier and Decision Tree Classifier displayed commendable performance, with solid accuracy rates of 87% and 89%, respectively. These models excel at accurately categorizing patients into the appropriate CKD stages, a critical aspect of healthcare.

The standout performer was the Random Forest Ensemble, consisting of 500 decision trees, delivering an outstanding overall accuracy of 92%. It exhibited high sensitivity, indicating proficiency in identifying genuine CKD cases, while its specificity level showcased its ability to rule out CKD in healthy patients. Precision demonstrated its accuracy in positive predictions, and the F1-score balanced accuracy with the prevention of missed cases. Crucially, minimizing false negatives is vital within the healthcare context to prevent delayed diagnoses and inadequate treatment, and the model places a particular emphasis on achieving this goal. A comparative analysis against established CKD prediction systems highlighted the significant superiority of this model, increasing sensitivity by 12% and specificity by 19% compared to one method, while its overall accuracy surpassed another method by a substantial 27%.

Furthermore, the model's capacity to handle missing data is noteworthy, addressing the challenges within Sri Lanka's healthcare infrastructure. One pivotal discovery was the superiority of ensemble-based models, specifically Random Forest and Decision Tree, which outperformed other algorithms in terms of accuracy. Hyperparameter tuning significantly improved the models' performance, emphasizing the importance of customizing algorithms to the local dataset's characteristics. Effective reduction of false negatives was a critical capability demonstrated by the models, ensuring the vigilant identification of high-risk patients. Moreover, the models exhibited resilience to data constraints, maintaining high accuracy levels even with incomplete patient records, a common scenario in Sri Lanka's healthcare landscape.

Algorithm	Risk Prediction	Staging Prediction
Random Forest	89%	87%
Decision Tree	-	89%
Logistic Regression	87%	-
SVM	84%	40%
Multinominal Naïve Bayes	79%	-

Table 5-Comparative accuracy of ML algorithms for CKD risk prediction

Medical image analysis using image processing

An extensive research study focused on the vital task of chronic kidney disease (CKD) detection through cutting-edge deep learning models, the performance of four models - MobileNet, EfficientNet, Xception, and Depthwise Separable ResNet - was thoroughly assessed. The primary objective was determining the most effective and accurate approach for this crucial medical application. During the development of the models, a notable technical challenge was encountered due to incompatible software versions that hindered GPU acceleration. To address this, the development pipeline was moved into a Windows Subsystem for Linux (WSL) environment, facilitating the interaction between TensorFlow and the GPU, significantly improving training efficiency.

Within the WSL environment, each model was trained using a substantial kidney CT scan slices dataset, necessitating meticulous hyperparameter tuning. Precision was identified as the most critical evaluation metric due to its paramount role in minimizing false positives in the medical domain. Notably, the Xception model consistently outperformed its counterparts in precision and displayed impressive performance in other key metrics such as recall, F1-Score, and ROC-AUC.

Nevertheless, selecting the optimal model should consider considerations beyond precision, including specific requirements of the medical use case, computational resources, and deployment constraints. Future research focuses on refining the Xception model, exploring ensemble methods, and enhancing performance by acquiring a more extensive and diverse clinical dataset.

Personalized dietary assessment using machine learning

Among the algorithms examined, including logistic regression, decision trees, neural networks, and random forest regressors, the random forest regressor emerged as the most promising candidate. This algorithm exhibited exceptional predictive accuracy and resilience when handling complex CKD patient data, including nonlinearities and intricate feature interactions. These findings guide future healthcare data analysts and underscore the importance of algorithm selection, highlighting the superiority of random forest regressors in CKD management. This discovery validates the study and contributes to the broader conversation on algorithmic alternatives in healthcare and their potential for more effective solutions.

Model Name	**Accuracy**
Decision Tree	99.32
Logistic Regression	88.59
Neural Network	88.22
Random Forest Regressor	99.93

Table 6-Comparative accuracy of ML algorithms for Dietary Prediction

Furthermore, extensive research into CKD management has yielded insights into improving the nutritional quality of CKD patients. A pivotal discovery revolves around developing a tailored diet for CKD patients in Sri Lanka. These meal plans are meticulously customized based on individual health profiles and serum potassium levels, providing a balanced approach to managing potassium intake and slowing disease progression. The research culminates in a user-friendly mobile application, serving as a beacon of hope for CKD patients. It equips them with practical, real-time dietary guidance and tools for active integration into their healthcare. These research findings signify a significant step towards enhancing the quality of life for CKD patients in Sri Lanka and contribute to the broader conversation on personalized dietary interventions for chronic diseases.

Smart Water Quality Monitoring for CKD Patients

The developed IoT system effectively integrates three sensors measuring pH, turbidity, and water temperature to provide real-time data on essential water quality parameters. This research component demonstrates the system's reliability and accuracy in monitoring water quality, especially in areas at risk of CKD in Sri Lanka. For CKD patients, this means having access to up-to-the-minute information about the safety of their drinking water, enabling informed decisions and immediate health protection measures.

A machine learning (ML) model was employed to enhance system accuracy, utilizing historical lab data from CKD-risk areas in Sri Lanka for training. The ML model offers location-specific insights into water quality, aiding early detection and proactive management of water quality issues crucial for CKD patients.

The research findings confirm the ML model's effectiveness in analyzing water quality data identifying trends, deviations, and potential risks based on location and monitored parameters.

A user-friendly mobile application was also developed, serving as a vital tool for CKD patients in Sri Lanka. It provides easy, real-time access to data collected by IoT sensors and analyzed by the ML model, ensuring patients are promptly informed about water quality issues that may affect their health.

In conclusion, the research culminates in an IoT and ML-based water quality monitoring system highly effective for Sri Lankan CKD patients. Combining real-time sensor data, ML analysis, and a user-friendly mobile application significantly improves the accessibility of accurate and timely information about drinking water quality. This advancement holds great potential to protect the health of CKD patients and empower them to make informed decisions about their water consumption.

3.3 Discussion

The research encompasses four critical components of a mobile application to address the complex challenges of chronic kidney disease (CKD) in Sri Lanka. These components, designed to enhance CKD management and patient care, include machine learning-based risk prediction, deep learning for image-based screening, personalized diet plans, and an IoT-based water quality monitoring system.

Chronic kidney disease (CKD) poses a growing global health concern, emphasizing the need for better screening, diagnosis, and personalized management. The research team developed a mobile application integrating machine learning capabilities to address this. This application empowers healthcare professionals to predict CKD risk and stage patients with over 80% accuracy. These risk predictions are a vital starting point for timely intervention and personalized treatment. Challenges include physician acceptance of AI-driven recommendations and integration with existing healthcare IT systems. However, implementing this predictive model can lead to improved patient care and outcomes and serve as a template for introducing predictive analytics into other clinical practices. On a societal level, this advancement can encourage self-management of health and positive lifestyle changes. Challenges to adoption include user-friendly interfaces and extensive user education. Despite its limitations, this research lays a promising foundation for future work in the intersection of machine learning and medicine, promising real-world impact.

The global burden of CKD continues to rise, necessitating improved screening and diagnosis methods. The research project introduces an innovative mobile application driven by deep learning for radiological screening. The results demonstrate the feasibility of using deep learning for image-based CKD screening, with MobileNet v2 as the top-performing model. While it still needs to surpass clinical experts, this approach can potentially enhance clinical workflow efficiency and access to care. Challenges include the need for further research, particularly with larger datasets, and addressing software environment challenges. The system could be extended to incorporate additional modalities beyond CT scans, enabling continuous risk assessment and early detection. The commercialization potential of the app is also highlighted, as it could be licensed to imaging equipment manufacturers. Governance frameworks are essential to ensure safe and ethical AI implementation, focusing on patient privacy, transparency, and equitable access.

Dietary management is crucial for CKD patients, and this research emphasizes the importance of tailored dietary protocols based on serum potassium levels and individual health data. The Random Forest Regressor emerged as a practical algorithm for predicting dietary needs. This personalized diet can reduce the progression of CKD and empower patients to participate in their healthcare actively. While this study is focused on CKD, the approach can be adapted for other chronic diseases, contributing to a holistic approach to healthcare.

Access to clean drinking water is essential for CKD patients, especially in regions at risk of contamination. The research introduces an IoT-based water quality monitoring system that provides real-time data on critical parameters. This real-time data accessibility is crucial for CKD patients and can significantly improve public health by detecting water contamination events promptly. The integration of calibrated sensors enhances data accuracy, contributing to the effectiveness of the monitoring system. Machine learning models further empower early detection and intervention, benefiting CKD patients and the broader population. The user-friendly mobile application offers an accessible interface for patients and can raise awareness about water quality issues, fostering community engagement.

The research findings and implications collectively represent a significant step forward in CKD management and public health in Sri Lanka. Integrating these components, driven by advanced technology and data-driven solutions, can transform CKD care and improve patient outcomes. Challenges and avenues for future research and development are identified, emphasizing the need for interdisciplinary collaboration, community engagement, and ethical AI implementation to maximize the benefits of these innovative solutions.

4 CONCLUSION

The development and implementation of this comprehensive mobile application represent a groundbreaking leap forward in the battle against chronic kidney disease (CKD) in Sri Lanka. This all-encompassing solution combines the power of advanced technologies, machine learning, medical imaging, personalized dietary guidance, and water quality monitoring to address the multifaceted challenges CKD patients face.

At its core, this application is a testament to the potential of technology-driven innovation in healthcare. Weaving together four essential components can revolutionize the detection, management, and understanding of CKD, setting a new standard for personalized patient care and public health.

The first component, centred around machine learning, signifies the transformation of CKD prediction and treatment. This research aims to enhance diagnostic accuracy, improve treatment effectiveness, and elevate patient outcomes by developing patient-specific models tailored to the Sri Lankan population. It is a profound commitment to advancing patient-centred care, and its implications extend throughout the Sri Lankan healthcare landscape.

The second component of this mobile application harnesses deep learning and medical imaging to augment CKD screening and care. It offers a promising approach that, while still in refinement, presents the potential to enhance clinical capabilities and accessibility for patients. Providing an intuitive mobile interface for patients to monitor their kidney health empowers individuals with the tools for proactive self-management.

The third component, focusing on personalized diet plans, addresses a critical issue for CKD patients in Sri Lanka. By leveraging machine learning, it offers tailored dietary recommendations, considering individual factors like blood parameters, medication usage, allergies, and dietary preferences. The categorization of patients into different zones based on disease severity is a significant achievement, paving the way for improved patient adherence and health outcomes.

The fourth and final component, the IoT and ML-based water quality monitoring system represents hope in combating water contamination—a pervasive health concern in Sri Lanka. Providing real-time, pinpoint-accurate water quality information through IoT devices and machine learning empowers CKD patients with timely, actionable insights into their water quality, enabling proactive measures to protect their health.

This mobile application marries these four crucial components and is a beacon of innovation and progress. It not only aims to improve patient outcomes and healthcare delivery but also has the potential to alleviate the daily burdens faced by CKD patients. Integrating advanced technologies and meticulous research offers a holistic approach to CKD management, addressing not only the disease itself but also the environmental factors that can exacerbate it.

While these components represent significant strides forward, it is essential to acknowledge the work yet to be done. These components' refinement, validation, and expansion are essential for their real-world effectiveness. Collaboration with healthcare professionals, user feedback, and a commitment to data quality is pivotal in translating these initial findings into scalable clinical tools.

As the journey of this mobile application continues, it holds the promise of transforming CKD management in Sri Lanka and serving as a model for similar programs worldwide. The convergence of innovation, dedication, and a profound commitment to healthcare advancement shines a light on the path toward a healthier, more informed society. By embracing the power of technology and machine learning in healthcare, this application stands as a symbol of hope and progress in the fight against chronic kidney disease.

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6 GLOSSARY

React Native	-	*A framework for building native mobile apps using React*
Flask	-	*A Python web framework*
MongoDB	-	*A document-oriented NoSQL database*
DICOM	-	*Digital Imaging and Communications in Medicine*
TensorFlow	-	*An open-source library for machine learning*
Redux	-	*A state management library for JavaScript apps*
Hyperparameter tuning	-	*Optimizing model parameters to improve performance*
AUC-ROC	-	*A performance metric for classification models*
JSON	-	*JavaScript Object Notation (data interchange format)*
CKD Stages	-	*Classifications of CKD severity based on glomerular filtration rate*
GFR	-	*Measures kidney function*
Precision	-	*Fraction of positive predictions that are correct*
Recall	-	*Fraction of actual positives correctly predicted positive*
F1-Score	-	*Harmonic mean of precision and recall*
Specificity	-	*True negative rate*
Sensitivity	-	*True positive rate*

7 APPENDICES

SRI LANKA
INSTITUTE OF INFORMATION TECHNOLOGY

16th Floor, BoC Merchant Tower, No. 28, St. Michael's Road, Colombo 03

Date:28/04/2023 Your Ref : My Ref :2023-032

Dr. Premil Rajakrishna,
Consultant Nephrologist,
Teaching Hospital,
Kurunegala.

Dear Sir,

Certifying the project titled "KidniFy - A mobile based Chronic kidney Disease Patient care System Using ML and IoT" is conducting as a BSc in IT final year research project.

The Sri Lanka Institute of Information Technology (SLIIT) is the largest Degree Awarding Institute in the field of information Technology recognized by the University Grants Commission under the Universities Act. It was established in the year 1999 to educate and train Information Technology (IT) Professionals required by the fast-growing IT Industry in Sri Lanka.

This letter is to certify that the following students.
IT20154226 - M.M.K.L.Marasinghe
IT20226596 - J.P.M.L. Perera
IT20235260 - D.R.N. Samarawila
IT20785120 - W.B.M.A. Isurika

They are final year undergraduate students who conduct research entitled "KidniFy - A mobile based Chronic kidney Disease Patient care System Using ML and IoT" as partial fulfillment of the B.Sc. in Information Technology degree at Sri Lanka Institute of Information Technology (SLIIT). The students are conducting the research under the supervision of Ms. Wishalya Vanshanee Tissera

I kindly request your assistance in enabling these students to collect data from your organization to build their dataset for the research project. If you have any questions or require further clarification about the project, please do not hesitate to contact me.

Thank you for your cooperation

....
Dr. Jayantha Amararachchi
Assistant Professor/
Research Project Coordinator,
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Active

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Request Datasets Related to Chronic kidney Disease Patients for Research Purpose External Inbox ×

Wishalya Tissera <wishalya.t@sliit.lk>

to premil3nadeekanth@gmail.com, Marasinghe, me, Samarawila, Isurika

Tue, May 2, 11:15 PM

Dear Dr. Premil Rajakrishna,

I'm sending this email to inform you that the students mentioned below are the 4th year students who are following BSc. (Hons) in Information Technology degree program at Sri Lanka Institute of Information Technology (SLIIT) and they are carrying out a final year research project related to kidney Diseases. The aim of this research is to develop a mobile application focusing on Chronic kidney Diseases.

Research group members:

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They will be visiting your hospital on the 3rd of May 2023, Wednesday, as a field visit and will need the access to the datasets and require the knowledge related to this discipline. A summary of the project and the dataset requirement has been attached with this email for your reference.

As the supervisor of this research project, I can confirm that these students have obtained all necessary permissions and approvals from SLIIT to conduct this research and I'll make sure that the students will handle the data ethically and solely for the research purpose without any misconduct.

I would be grateful if you could provide the access to the requested datasets and required knowledge during their visit to your hospital. If you require any further information or clarification, please do not hesitate to contact me. Thank you in advance.

Supervisor Name: Ms. Wishalya Tissera
Tel (Direct): 0117544110
Mobile: 0769427655
Email: wishalya.t@sliit.lk

Best Regards,
Wishalya Tissera.
MCS (UCSC), BSc. Hons in IT (SLIIT)