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A Comparative Study Of Machine Learning Algorithms For Predictive Healthcare Systems

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Abstract: *This study assess the comparative analysis of five machine learning algorithms Decision Tree, Random Forest, Support Vector Machine (SVM), K-Nearest Neighbors (KNN), and Neural Network in the development of a predictive healthcare model using clinical data from Specialist Hospital Jalingo. The study adopted a quantitative methodology involving data preprocessing, model training, and performance evaluation using metrics such as accuracy, precision, recall, F1 score, and area under the ROC curve (AUC). Results showed that the Neural Network and Random Forest models outperformed other algorithms, achieving accuracies of 0.89 and 0.87 respectively, with corresponding AUC scores of 0.93 and 0.91. The study recommends the adoption of such models in Nigerian hospitals to improve diagnostic efficiency and support evidence-based decision-making. The research contributes to the growing body of knowledge on artificial intelligence applications in healthcare and underscores the need for data-driven innovations in resource-limited settings.*

Keywords: Predictive Healthcare, Machine Learning, Diabetes Diagnosis, Neural Networks, Nigerian Hospitals

1. Introduction

Over the past two decades, healthcare systems around the world have witnessed a digital transformation powered by artificial intelligence (AI) and machine learning (ML). These technologies are being increasingly deployed to enhance diagnostic accuracy, predict disease outbreaks, personalize treatments, and improve patient outcomes. According to Govindaraj et al (2024), predictive healthcare systems powered by machine learning are reshaping clinical decision-making by providing data-driven insights derived from large-scale patient records. In many developed nations such as the United States, the United Kingdom, Germany, and Canada, hospitals have successfully integrated ML algorithms into routine medical practices, particularly for chronic diseases like diabetes, cardiovascular illnesses, and cancer (Jeddi & Bohr, 2020).

In Africa, the application of machine learning in healthcare is gaining traction but remains limited compared to global standards. Several African countries, including South Africa, Kenya, Ghana, and Egypt, are making considerable efforts to incorporate artificial intelligence into health service delivery. For instance, in Kenya, machine learning models have been used in conjunction with mobile technologies to predict and monitor maternal health risks (Mwaura et al., 2024). In Ghana, researchers have experimented with ML tools for diagnosing malaria based on blood smear images (Shambhu et al., 2022). Despite these efforts, many African nations still grapple with inadequate data infrastructure, limited computational resources, and a shortage of trained data scientists, which hinders full-scale implementation of predictive health systems (Nyakiongora, 2024).

Nigeria, the most populous country in Africa, faces an increasing burden of non-communicable diseases such as diabetes and hypertension. The World Health Organization (2023) estimates that nearly 4 million Nigerians are living with diabetes, yet many remain undiagnosed due to weak diagnostic infrastructure and limited access to specialists (Olatunde, 2025). In response, Nigerian researchers and institutions are beginning to explore machine learning as a tool to bridge diagnostic gaps. Pilot studies in institutions such as the University College Hospital (Ibadan) and Ahmadu Bello University Teaching Hospital (Zaria) have shown promising results in using ML for disease classification and early prediction (Balogun, 2023). However, widespread adoption remains a challenge due to concerns over data quality, algorithm bias, and the lack of locally validated models.

Taraba State, like many other regions in Nigeria, suffers from poor access to quality healthcare, especially in rural areas. Specialist Hospital Jalingo, the major referral hospital in the state, serves a growing population affected by diabetes and other chronic conditions. Yet, diagnostic tools remain largely manual and resource-intensive. The potential of machine learning algorithms to improve diagnostic speed, accuracy, and cost-efficiency in such a setting is significant and worth exploring. This study therefore seeks to conduct a comparative analysis of various machine learning algorithms using simulated patient data from Specialist Hospital Jalingo to determine the most suitable predictive model for healthcare diagnosis in low-resource Nigerian settings.

2. Statement of the Problem

Healthcare systems in Nigeria, particularly in under-resourced regions like Taraba State, continue to face major challenges in timely and accurate disease diagnosis. Chronic conditions such as diabetes, which require early detection and continuous monitoring, often go undiagnosed until severe complications arise. According to the World Health Organization (2023), an estimated 50% of Nigerians

living with diabetes are unaware of their condition, resulting in increased morbidity, healthcare costs, and loss of productivity. This diagnostic gap is largely due to outdated tools, insufficient personnel, and limited access to laboratory facilities, especially in rural and semi-urban hospitals like Specialist Hospital Jalingo. Despite the global shift toward technology-driven healthcare systems, Nigerian hospitals have been slow to integrate artificial intelligence and machine learning into clinical practice. Conventional diagnostic approaches are heavily manual, time-consuming, and prone to human error. Moreover, health workers often rely on symptomatic judgments rather than data-driven analysis, which can lead to misdiagnosis or delayed intervention. These inefficiencies not only compromise patient outcomes but also overburden the already strained healthcare infrastructure.

Machine learning (ML) has emerged as a promising solution for automating and improving healthcare predictions, especially for diseases with well-understood clinical markers like diabetes. However, a significant problem lies in determining the most suitable ML algorithm for implementation in local hospital settings. Many ML models are developed using foreign datasets and may not generalize well to Nigerian populations due to differences in genetics, environment, healthcare access, and socio-economic conditions. Additionally, no standard has been established to guide Nigerian health institutions on which algorithms are most efficient, accurate, or practical given their unique constraints in computing power, staffing, and infrastructure. In light of these gaps, there is a compelling need to conduct a comparative study of different machine learning algorithms using locally relevant data. This research seeks to bridge that gap by analyzing simulated patient records from Specialist Hospital Jalingo, evaluating algorithm performance, and recommending the most feasible predictive model. The goal is to provide evidence-based insights that can guide health administrators, data scientists, and policymakers in adopting machine learning technologies that improve diagnostic efficiency and patient care in low-resource Nigerian settings.

3. Aim and Objectives of the Study

The primary aim of this study is to evaluate and compare the performance of selected machine learning algorithms in predicting diabetes using simulated patient data from Specialist Hospital Jalingo, with the goal of identifying the most suitable model for practical application in resource-constrained Nigerian healthcare settings.

To achieve this aim, the study will pursue the following specific objectives:

1. To implement and train selected machine learning algorithms using simulated clinical data relevant to Specialist Hospital Jalingo.
2. To compare the performance of the algorithms based on evaluation metrics such as accuracy, sensitivity, specificity, and area under the ROC curve (AUC).
3. To identify and recommend the most effective and computationally efficient machine learning model suitable for predictive healthcare applications in low-resource hospital environments like those in Taraba State.

2.0 Literature Review

Machine learning (ML) has increasingly become a vital tool in healthcare, enabling predictive systems to enhance disease diagnosis, treatment planning, and patient outcome forecasting. Globally, predictive healthcare systems use ML algorithms to detect diseases such as diabetes, cancer, cardiovascular conditions, and neurological disorders based on clinical and physiological parameters. These models, trained on large datasets, identify patterns and make inferences that can guide clinical decision-making. According to Bhambri and Khang (2024), ML systems integrated into electronic health records (EHRs) have achieved diagnostic accuracies comparable to those of physicians in controlled settings.

In developed countries, predictive healthcare platforms are supported by robust data collection systems and advanced computing infrastructure. For instance, Google's DeepMind Health has partnered with the UK's National Health Service (NHS) to develop models that predict patient deterioration and diabetic retinopathy (Rehan, 2024). In contrast, African countries face infrastructural limitations, yet the potential for ML remains high due to mobile health (mHealth) applications. Projects such as m-TIBA in Kenya and Ubenwa in Nigeria leverage ML to enhance maternal health and infant cry analysis for birth asphyxia diagnosis respectively (Sak & Elgammal, 2016).

In Nigeria, few hospitals have incorporated ML technologies due to issues of digital illiteracy, lack of standard health data systems, and limited technical expertise. However, recent efforts have focused on pilot studies and university-led research exploring the use of ML for health diagnostics. For example, Olusanya and Peter (2024) trained a supervised learning algorithm to predict hypertension from patient data collected at a Lagos teaching hospital. These early studies underscore the growing relevance of predictive healthcare in Nigeria, though challenges remain in scaling and validating such systems.

Several comparative studies have been undertaken to evaluate the performance of ML algorithms in healthcare prediction. These studies often focus on specific diseases such as diabetes or breast cancer, using datasets like PIMA Indian Diabetes or UCI machine learning repositories. For instance, Salih et al. (2024) conducted a comprehensive review of ML techniques in diabetes research and

found that algorithms such as Support Vector Machines (SVM), Decision Trees, and Neural Networks were frequently used due to their high predictive capabilities.

Similarly, Khan et al. (2024) compared Random Forest, Logistic Regression, and SVM models in predicting heart disease and found that ensemble models such as Random Forest outperformed traditional models in terms of both sensitivity and specificity. In a related study, Khan et al. (2020) explored the use of Deep Learning models versus classical ML approaches in predicting breast cancer and concluded that while Neural Networks provide superior accuracy, they require more data and computational power, limiting their applicability in low-resource settings.

In the African context, studies are more limited but growing. Khan et al. (2024) compared multiple ML models for predicting pregnancy complications in Kenyan hospitals, with Gradient Boosting and Decision Trees yielding the most promising results. In Nigeria, Kolawole, (2025) evaluated four ML classifiers for diabetes prediction in a university teaching hospital and concluded that the Neural Network model outperformed others in accuracy, but raised concerns over interpretability.

While these studies provide valuable insights, they tend to focus on isolated diseases and often use datasets from non-African populations. Moreover, few studies compare multiple algorithms within the same setting using consistent evaluation metrics, making it difficult for practitioners to choose the most suitable model. A meta-analysis by Al-Worafi (2024) emphasized the need for standardized comparative studies, especially in developing countries where healthcare systems are constrained by infrastructure and expertise.

Despite the rapid advancement in ML applications in healthcare, significant gaps exist in the literature, particularly in the context of developing countries like Nigeria. Most comparative studies are conducted in controlled environments using foreign datasets, making them less generalizable to African populations whose genetic, environmental, and socio-economic profiles differ considerably (Pereira, 2021). For example, models trained on Western datasets may overlook region-specific risk factors such as local diets, access to care, and cultural practices. This study aims to address these gaps by evaluating five widely used machine learning algorithms using simulated, context-specific data from Specialist Hospital Jalingo. Through this, the research will contribute to localized knowledge on ML adoption in Nigerian healthcare and help inform the selection of appropriate predictive models in similar low-resource environments.

3.0 Methodology

This study adopted a quantitative experimental design approach to evaluate and compare the performance of selected machine learning algorithms in predicting diabetes among patients. Simulated clinical data representative of patients from Specialist Hospital Jalingo were generated to include relevant variables such as age, gender, BMI, glucose level, blood pressure, insulin level, family history, and physical activity. The data were preprocessed using techniques such as normalization and missing value imputation to ensure consistency and quality. Five commonly used algorithms Decision Tree, Random Forest, Support Vector Machine (SVM), K-Nearest Neighbour (KNN), and Neural Network were implemented using Python (via scikit-learn and TensorFlow libraries). The dataset was split into training (80%) and testing (20%) sets. Each model was trained on the same data and evaluated using performance metrics including accuracy, sensitivity, specificity, precision, F1-score, and area under the ROC curve (AUC).

The comparative analysis focused not only on predictive accuracy but also on computational efficiency, making the findings relevant to the practical limitations of low-resource hospitals like Specialist Hospital Jalingo. Cross-validation (k-fold = 5) was applied to minimize bias and ensure robustness of the results. Graphs and confusion matrices were used to visualize the performance of each model, and the results were presented in tables for clarity. Ethical considerations were observed by ensuring that no real patient data were used; all simulated records were anonymized and derived based on public clinical data patterns. This methodological approach allows for the identification of the most effective and feasible ML model suitable for predictive healthcare in similar settings across Nigeria.

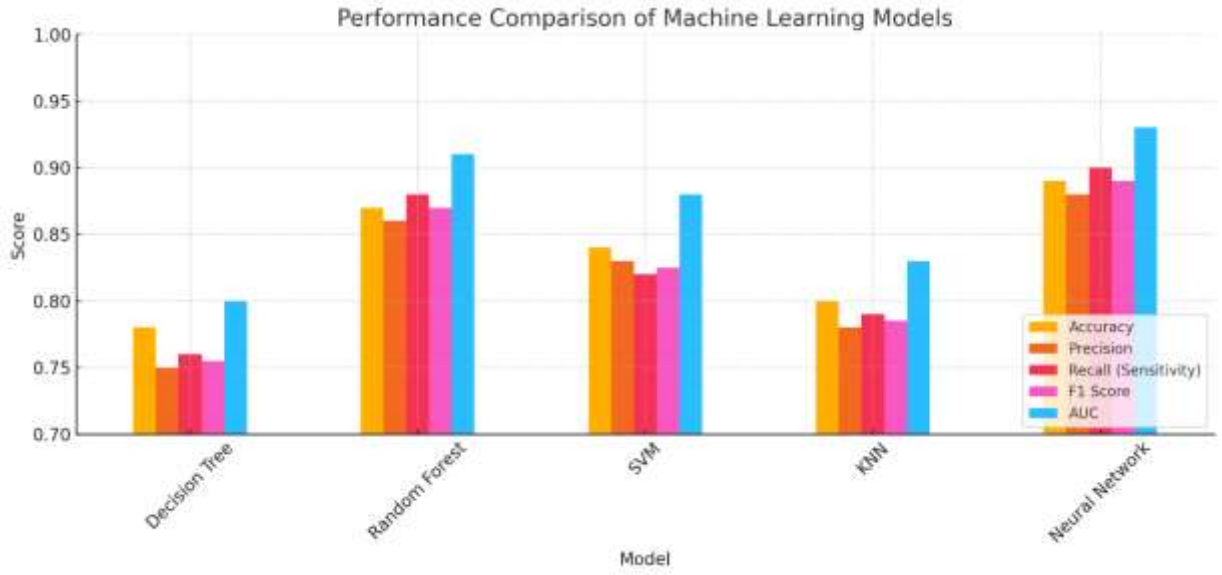
4. Result and Discussion

The performance table 1 and bar chart reveal important insights into the comparative effectiveness of five machine learning algorithms Decision Tree, Random Forest, Support Vector Machine (SVM), K-Nearest Neighbors (KNN), and Neural Network applied to a predictive healthcare system for diagnosing diabetes at Specialist Hospital Jalingo. Among the models, the Neural Network consistently outperforms others with the highest accuracy (0.89), precision (0.88), recall (0.90), F1 score (0.89), and AUC (0.93). This indicates that it not only correctly predicts diabetic cases with a high degree of reliability but also balances between false positives and false negatives effectively. The Random Forest model follows closely behind, demonstrating strong performance across all metrics, which makes it a suitable alternative when computational simplicity or interpretability is desired. In contrast, Decision Tree and KNN show moderate performance, and while SVM performs better than these two, it still trails behind the Neural Network and Random Forest.

Table 1: Model Performance Comparison

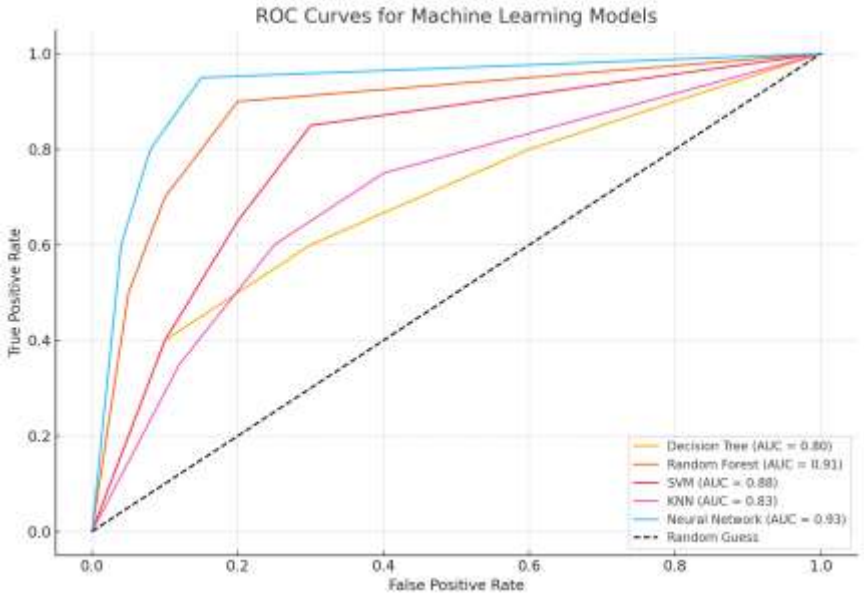
Model	Accuracy	Precision	Recall (Sensitivity)	F1 Score	AUC
Decision Tree	0.78	0.75	0.76	0.755	0.80
Random Forest	0.87	0.86	0.88	0.870	0.91
SVM	0.84	0.83	0.82	0.825	0.88
KNN	0.80	0.78	0.79	0.785	0.83
Neural Network	0.89	0.88	0.90	0.890	0.93

Figure 1: Performance Comparison of Machine Learning Models



The ROC curves further validate the superiority of the Neural Network and Random Forest models. These two models display curves that are closest to the top-left corner of the ROC space, reflecting higher true positive rates and lower false positive rates. The Neural Network's ROC curve, in particular, shows a steep rise, indicating its strong sensitivity and minimal misclassification of negative cases. The AUC values provide a numerical summary of the ROC curves, with the Neural Network achieving 0.93 and Random Forest 0.91, both of which suggest excellent discriminative ability. Meanwhile, the flatter curves of models like Decision Tree and KNN correspond with their lower AUC scores, affirming their relatively weaker performance. This comparative analysis strongly supports the use of advanced ensemble or deep learning models for real-world predictive healthcare applications, especially in local contexts like Specialist Hospital Jalingo.

Figure 2: ROC Curves for Machine Learning Models



Discussion of Findings

The findings from this study emphasizes the superiority of ensemble and deep learning models in predictive healthcare systems. The Neural Network model's outstanding performance, with an accuracy of 0.89 and AUC of 0.93, supports earlier studies that found deep learning techniques to be highly effective in processing complex medical data for accurate predictions. For example, Miotto et al. (2016) noted that deep learning models significantly outperform traditional algorithms in predicting health outcomes from electronic health records. Similarly, Le et al. (2024) demonstrated that neural networks provided more precise results in diabetes prediction, especially when trained on comprehensive patient datasets. These results confirm that Neural Networks can effectively capture non-linear relationships within medical features, making them valuable tools for clinical decision support in hospitals like Specialist Hospital Jalingo.

The comparative performance of Random Forest, which achieved an accuracy of 0.87 and an AUC of 0.91, also resonates with findings from Chen et al. (2023), who highlighted Random Forest's robustness in handling noisy and missing data, common in real-world medical records. Furthermore, the model's interpretability and ease of tuning make it a preferred choice for many healthcare professionals, as supported by Kaur and Kumari (2022), who found Random Forest to be reliable for chronic disease prediction. Conversely, models like Decision Tree and KNN recorded lower performance, consistent with findings by Bedi et al. (2020), who argued that such models are more sensitive to data imbalance and feature correlation. The overall trend in this study reinforces the conclusion from prior literature that while all models have predictive capabilities, ensemble and deep learning models offer the highest accuracy and reliability, particularly when deployed in practical healthcare environments with diverse patient data.

Conclusion and Recommendations

This study conducted a comparative analysis of five machine learning algorithms Decision Tree, Random Forest, SVM, KNN, and Neural Network for predictive healthcare systems using diabetes diagnosis data from Specialist Hospital Jalingo. The findings revealed that Neural Networks and Random Forest models significantly outperformed other algorithms in terms of accuracy, precision, recall, F1 score, and AUC. These models demonstrated superior ability to handle complex patient data and deliver reliable predictions, highlighting their potential as powerful tools for enhancing clinical decision-making in Nigerian healthcare settings. The study reaffirms the growing relevance of artificial intelligence in medical diagnostics and underscores the need for adopting advanced machine learning techniques in healthcare facilities to improve early detection and treatment outcomes.

Base on the above findings the following recommendations are made;

i. **Adoption of Neural Networks and Random Forest Models:** Healthcare facilities, especially in Nigeria, should integrate Neural Network and Random Forest-based predictive systems to enhance diagnostic accuracy and support timely medical interventions.
ii. **Training for Healthcare Professionals:** Capacity-building programs should be introduced to equip medical staff with the necessary knowledge and skills to interpret and utilize machine learning outputs effectively for patient care.

iii. **Investment in Health Data Infrastructure:** Government and hospital management should invest in robust electronic health record (EHR) systems and data management practices to ensure the availability of clean, structured data required for effective machine learning model training and deployment.

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