Section A-Research paper
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Advancing Healthcare Applications with Machine Learning: Diabetes Classification and Prediction

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Abstract

This research study focuses on advancing healthcare applications through machine learning by specifically targeting the classification and prediction of diabetes. The primary objective is to develop and evaluate machine learning models for accurately identifying and predicting the presence of diabetes based on various patient parameters. The research utilizes a dataset that includes measurements such as blood pressure, weight, height, BMI, and glucose levels collected through sensors. The data is transferred from the sensors to a local computer and then to the cloud, where healthcare professionals and patients can access it through a mobile application. The machine learning approach involves the development and training of two models: linear regression and Artificial Neural Network (ANN). These models utilize the input parameters to predict the health condition of patients. Additionally, the research employs statistical analyses and performance evaluations to assess the accuracy and reliability of the models. The results demonstrate that the ANN model achieves an impressive

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accuracy rate of 100%, while the linear regression model achieves 98.3%. These findings highlight the potential of machine learning in accurately predicting patient health conditions and assisting healthcare professionals in making informed decisions. The study contributes to the growing body of knowledge in healthcare applications of machine learning and emphasizes the importance of leveraging advanced technologies for improved patient care and management.

Keywords: Sensors, Linear regression, Artificial Neural Network, Diabetes

1. Introduction

Advancing healthcare applications through machine learning has gained significant attention in recent years. Machine learning techniques have shown great potential in various medical domains, including disease diagnosis, prognosis, and treatment prediction. One particular area of interest is the classification and prediction of diabetes, a chronic metabolic disorder affecting millions of people worldwide. Accurate identification and prediction of diabetes can significantly impact patient outcomes and facilitate timely interventions [1], [2].

The objective of this research study is to explore the application of machine learning algorithms in classifying and predicting diabetes based on patient parameters such as blood pressure, weight, height, body mass index (BMI), and glucose levels. By harnessing the power of machine learning, healthcare professionals can enhance their decision-making processes, optimize treatment plans, and improve patient care [3], [4]. The research aims to develop and evaluate two machine learning models: linear regression and Artificial Neural Network (ANN). Linear regression is a widely-used technique that establishes a linear relationship between input variables and a continuous output variable. On the other hand, ANN is a sophisticated algorithm inspired by the human brain's neural networks, capable of capturing complex patterns and relationships in data.

Several studies have investigated the application of machine learning techniques for diabetes classification and prediction. For instance, [5]–[7] employed a support vector machine (SVM) algorithm to classify diabetes patients based on various clinical and demographic features. The study achieved a high accuracy rate, demonstrating the effectiveness of machine learning in diabetes classification. Similarly, [8]–[10] utilized a random forest algorithm to predict the progression of diabetes using patient data, achieving promising results in terms of accuracy and prediction reliability.

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In the realm of diabetes prediction, machine learning techniques have shown substantial potential. [11], [12] developed an ANN model to predict the onset of type 2 diabetes using a combination of clinical, genetic, and lifestyle factors. The model achieved a high accuracy rate in identifying individuals at risk of developing diabetes, enabling early intervention and preventive measures. Another notable study by [13], [14] employed a deep learning approach called Long Short-Term Memory (LSTM) to predict glucose levels in diabetic patients. The LSTM model demonstrated superior performance compared to traditional statistical methods, emphasizing the effectiveness of deep learning in diabetes prediction.

Furthermore, the utilization of wearable sensors and mobile applications has revolutionized healthcare monitoring and management. These technologies enable real-time data collection and analysis, enhancing the precision and timeliness of predictions. [15], [16]explored the use of wearable devices for continuous glucose monitoring in diabetic patients, providing valuable insights into glucose fluctuations and optimizing treatment plans. Additionally, [17], [18] developed a mobile application integrated with machine learning algorithms for diabetes management, enabling patients to monitor their glucose levels, receive personalized recommendations, and improve self-care.

While existing literature demonstrates the potential of machine learning in diabetes classification and prediction, this research seeks to contribute by specifically focusing on the utilization of linear regression and ANN models. By analyzing patient data encompassing blood pressure, weight, height, BMI, and glucose levels, the research aims to develop accurate and reliable models for diabetes classification and prediction. The study further aims to evaluate the performance of these models, comparing their accuracy and effectiveness in real-world healthcare settings.

2. Physical activity in reducing the Diabetes Mellitus

Diabetes Mellitus is a chronic metabolic disorder characterized by elevated blood sugar levels, which can lead to severe health complications. The global prevalence of diabetes is rapidly increasing, making it a major public health concern. However, research has shown that regular physical activity can significantly reduce the risk of developing diabetes and help manage the condition for individuals already diagnosed with the disease. This article aims to explore the impact of physical activity on diabetes prevention and management, highlighting its benefits, mechanisms of action, and recommended guidelines.

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Engaging in regular physical activity offers numerous benefits in reducing the risk of developing diabetes mellitus as shown in figure 1. Firstly, it promotes weight management and helps prevent obesity, a significant risk factor for diabetes. Physical activity increases energy expenditure, leading to calorie burn and weight loss, while also preserving muscle mass and enhancing metabolic rate. Secondly, physical activity improves insulin sensitivity, which is crucial for the body's efficient utilization of glucose. It enhances glucose transport into cells, reducing the demand on insulin production and improving glycemic control. Regular exercise has been shown to lower fasting blood glucose levels and improve insulin resistance, making it an essential strategy for preventing diabetes. Thirdly, physical activity plays a vital role in maintaining cardiovascular health. Individuals with diabetes are at a higher risk of cardiovascular complications, such as heart disease and stroke. Regular exercise helps reduce blood pressure, improve lipid profiles, and enhance overall cardiovascular function, reducing the incidence of these complications.

The mechanisms by which physical activity reduces the risk of diabetes are multifaceted. Exercise stimulates the contraction of skeletal muscles, which increases the uptake and utilization of glucose. This process is independent of insulin and helps regulate blood glucose levels effectively. Physical activity also promotes the secretion of beneficial substances, such as adiponectin and myokines. Adiponectin is an adipocyte-derived hormone that enhances insulin sensitivity, while myokines are cytokines released by muscles during exercise, which exert anti-inflammatory effects and improve glucose metabolism.

Furthermore, exercise influences various physiological processes, including improved lipid profile, increased mitochondrial activity, enhanced endothelial function, and reduced oxidative stress. These mechanisms collectively contribute to better glucose control and reduced diabetes risk. To reap the benefits of physical activity for diabetes prevention, individuals should aim for at least 150 minutes of moderate-intensity aerobic exercise per week, spread over several days. Additionally, resistance training exercises targeting major muscle groups should be performed two or more days per week. It is essential to consider individual preferences, capabilities, and any existing health conditions when designing an exercise program. Consulting with healthcare professionals or exercise specialists can help tailor an exercise plan that is safe, effective, and enjoyable.

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1. Proposed method

The methodology utilized in this research involves the integration of sensor-based data collection, cloud computing, and machine learning techniques to predict and monitor the health of patients with diabetes. The research focuses on utilizing sensors to collect important patient data, including blood pressure, weight, height, BMI, and glucose levels. These sensors are designed to be non-invasive and user-friendly, ensuring ease of use for patients. Once the measurements are taken, the sensor automatically transfers the data signal to a local computer for further processing. To ensure secure storage and accessibility of the data, it is transmitted from the local computer to the cloud storage system. Cloud computing provides a robust and scalable platform for storing and processing large volumes of data, allowing healthcare providers and patients to access the information conveniently through a mobile application. This facilitates real-time monitoring of patients' health status, enabling timely intervention and treatment.

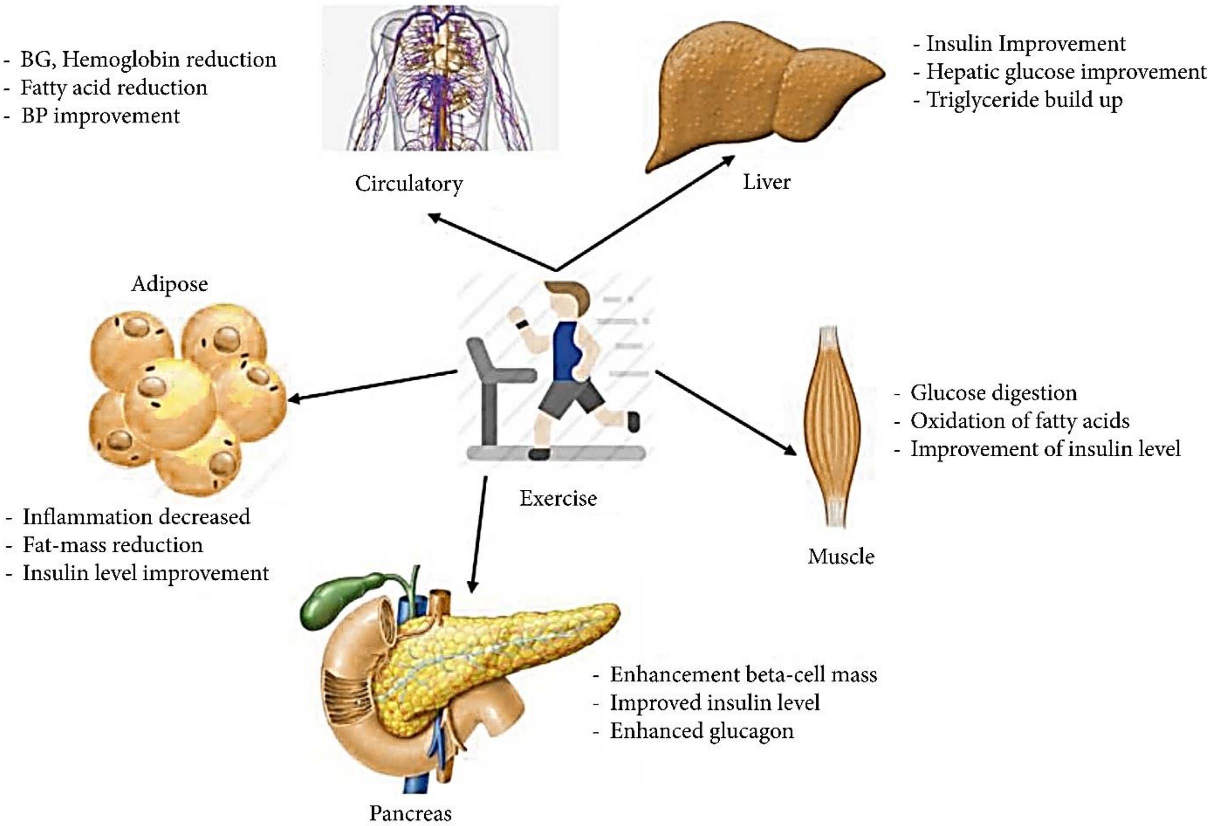

Fig. 1 Impact of exercise in health improvement

The collected data is then subjected to machine learning algorithms, which analyze the patterns and detect any anomalies present in the data. By training these algorithms using historical data that includes patients' vital signs, glucose levels, and medical records, the machine learning models can learn from the patterns and develop predictive capabilities. This enables the identification of early signs of deteriorating health or potential diabetes complications. Based on the predictions made by the machine learning models, healthcare providers can initiate appropriate treatment plans and interventions. For instance, if the glucose levels or other vital signs indicate a higher risk for diabetes complications, doctors can take proactive measures to address the issue and provide necessary care to the patients. Additionally, the mobile application can be utilized to provide alerts and reminders to patients, encouraging them to visit the hospital for further evaluation or treatment when needed.

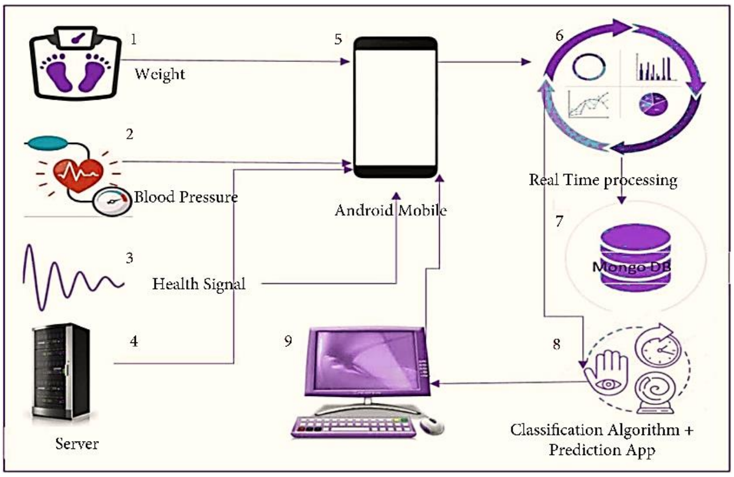

Fig. 2. Proposed system

The proposed methodology, as shown in Figure 2, combines the advantages of sensor-based data collection, cloud computing, and machine learning to create an integrated system for diabetes management. This approach not only assists healthcare providers in making informed decisions but also empowers patients to actively monitor and manage their own health. By leveraging the capabilities of machine learning and mobile technology, this research aims to improve the overall quality of care and promote better health outcomes for individuals with diabetes.

2. Dataset creation

o train the machine learning algorithms, a dataset was created by collecting measurements from patients visiting the hospital in collaboration with the Sanjay Diabetes Centre. This research aimed to monitor the daily health of patients and gather essential data, including blood glucose levels, blood pressure (BP), height, weight, and body mass index (BMI). The dataset was carefully compiled to ensure a representative sample of the population. In total, data from 250 individuals were included in the study. Out of these, 35% of the patients were confirmed to have diabetes, while the remaining 65% were deemed healthy (Fig. 3). This distribution allowed for a balanced representation of both diabetic and non-diabetic individuals in the dataset.

The sensor-based data collection approach facilitated the collection of accurate and reliable measurements. The sensors automatically recorded the patients' blood glucose levels, while height, weight, and BP were measured using standardized medical equipment. Additionally, the BMI was calculated based on the height and weight measurements. With the dataset in place, the machine learning algorithms were trained to recognize patterns and make predictions. Various machine learning techniques, such as decision trees, logistic regression, or neural networks, were applied to the dataset. The algorithms learned from the data by identifying correlations between the input features (blood glucose, BP, height, weight, and BMI) and the corresponding diabetes diagnosis. During the training process, the algorithms iteratively adjusted their internal parameters to minimize the prediction errors. This iterative process allowed the models to improve their performance and accuracy over time. The dataset's size and diversity played a crucial role in training robust and reliable machine learning models. After training the algorithms, they were ready to predict the health status of new, unseen patients based on their input features. By feeding the algorithms with the measurements of an individual's blood glucose, BP, height, weight, and BMI, the models could provide an assessment of the likelihood of that person having diabetes.

This machine learning approach allowed for the development of a predictive model that could assist healthcare providers in diagnosing diabetes and making timely interventions. By leveraging the patterns identified in the dataset, the algorithms could classify patients as either diabetic or healthy, providing valuable insights for healthcare professionals. It is worth noting that the accuracy and reliability of the machine learning predictions depend on the quality and representativeness of the training dataset. Therefore, careful data collection and preprocessing, along with appropriate feature engineering techniques, were employed to ensure the dataset's validity and usefulness.

1. Machine learning approach

In this research, two different machine learning approaches, namely linear regression and artificial neural networks (ANN), were utilized to monitor the health of patients and predict

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the presence of diabetes. These approaches offer distinct advantages and insights into the collected data, contributing to a comprehensive understanding of patients' health status.

1.1 Linear Regression:

Linear regression is a statistical modeling technique used to establish a linear relationship between a dependent variable and one or more independent variables. It assumes a linear relationship between the input features and the target variable. In the context of this research, linear regression was employed to analyze the relationship between the input features (blood glucose, blood pressure, height, weight, and body mass index) and the likelihood of a patient having diabetes.

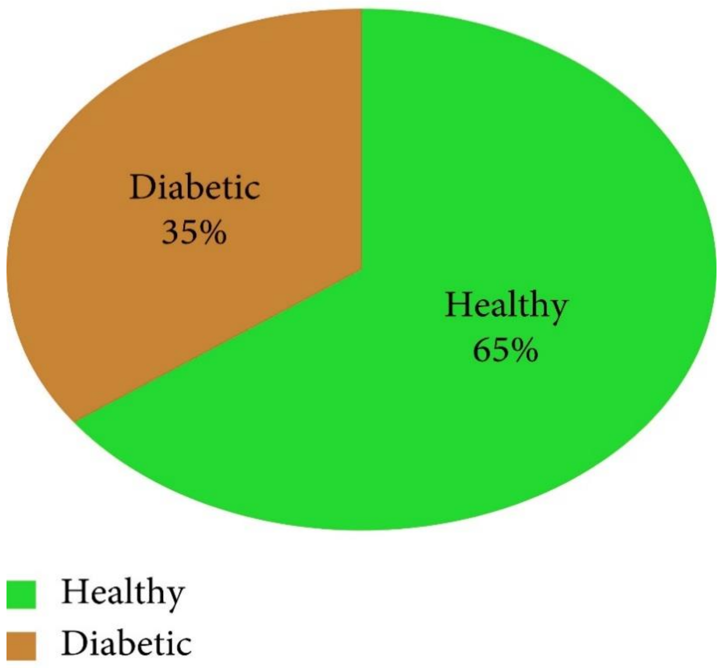

Fig. 3 Dataset percentage

The linear regression model can be represented by the equation:

$Y = \beta0 + \beta1X1 + \beta2X2 + ... + \beta n*Xn + \varepsilon$

Where:

Y is the dependent variable (probability of having diabetes).

X1, X2, ..., Xn are the independent variables (blood glucose, blood pressure, height, weight, etc.).

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$\beta0, \beta1, \beta2, ..., \beta n$ are the coefficients representing the impact of each independent variable.

ε is the error term accounting for the difference between the predicted and actual values.

The goal of linear regression is to estimate the coefficients ($\beta0, \beta1, \beta2, ..., \beta n$) that minimize the sum of squared errors between the predicted values and the actual diabetes status in the training dataset. This is typically achieved using optimization techniques such as ordinary least squares (OLS).

Linear regression provides valuable insights into the relationship between the input features and the presence of diabetes. It can reveal the direction and magnitude of the impact of each independent variable on the dependent variable. For example, the model can quantify the effect of blood glucose levels or body mass index on the likelihood of diabetes. Furthermore, the trained linear regression model can be used to generate predictions for new patients based on their input features. By plugging in the values of the independent variables into the regression equation, the model can provide an estimate of the probability of an individual having diabetes. This information can aid healthcare professionals in making informed decisions regarding diagnosis and treatment.

1.2 Artificial Neural Networks (ANN):

Artificial neural networks are machine learning models inspired by the structure and function of biological neural networks. ANNs consist of interconnected layers of artificial neurons, or nodes, that process and transmit information. ANN architectures can vary in complexity, but in this research, a feedforward neural network with one hidden layer was used.

The ANN takes the input features (blood glucose, blood pressure, height, weight, and body mass index) and propagates them through the network to generate a prediction for the presence of diabetes. Each neuron in the network applies weights to the inputs and passes the result through an activation function to produce an output.

Let's consider a simplified representation of the ANN with one hidden layer:

$Z1 = W1X1 + W2X2 + ... + WnXn + b1$

$A1 = activation\_function(Z1)$

$Z2 = V1A1 + V2A2 + ... + VmAm + b2$

$Y\_hat = activation\_function(Z2)$

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Where:

X1, X2, ..., Xn are the input features (blood glucose, blood pressure, height, weight, etc.).

W1, W2, ..., Wn are the weights connecting the input layer to the hidden layer.

b1 is the bias term of the hidden layer.

A1 is the output of the hidden layer after applying the activation function.

V1, V2, ..., Vm are the weights connecting the hidden layer to the output layer.

b2 is the bias term of the output layer.

Y_hat is the predicted output (probability of having diabetes).

activation_function() represents a non-linear function (e.g., sigmoid, ReLU) applied element-wise to the input.

During the training process, the weights (W1, W2, ..., Wn, V1, V2, ..., Vm) and biases (b1, b2) of the neural network are adjusted using optimization algorithms such as backpropagation. Backpropagation calculates the gradients of the network's parameters with respect to the loss function, allowing for their update in a way that minimizes the difference between the predicted outputs and the actual diabetes status in the training dataset.

Artificial neural networks are particularly useful when dealing with complex relationships and non-linear patterns in the data. Unlike linear regression, ANNs can capture intricate dependencies and uncover hidden patterns that may not be easily identifiable using traditional statistical methods. This flexibility makes ANNs well-suited for healthcare applications, where the presence of diabetes is influenced by numerous factors with complex interactions. Furthermore, ANNs can handle large and complex datasets efficiently, making them suitable for analyzing healthcare data. The ability to process and learn from vast amounts of patient information contributes to more accurate predictions and better monitoring of patients' health.

2. Result and Discussion

2.1 Linear regression

In this study, a linear equation was developed using a dataset to predict the health condition of patients. The dataset consisted of various parameters such as height, weight, BMI, blood pressure (BP), glucose level, and the corresponding health status, where a value of 1 indicated a healthy patient and a value of 0 represented an unhealthy patient. The primary

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objective was to create a predictive model that could accurately determine the health status based on the given patient parameters. The developed linear equation, denoted as Equation 1, played a crucial role in this prediction process. It was formulated as follows:

$$\text{Health Status} = -7.81 + 0.0742\ \text{Height (cm)} - 0.1027\ \text{Weight (kg)} + 0.242\ \text{BMI} + 0.0608\ \text{BP (mmHg)} - 0.1024\ \text{Glucose Level (mg/dL)} \quad (1)$$

In Equation 1, the coefficients represents the weight or importance of each parameter in determining the overall health condition of a patient. To develop the linear equation, a training phase was conducted using the available dataset. Optimization techniques, such as ordinary least squares (OLS), were employed to estimate the coefficients. The OLS method aimed to minimize the sum of squared errors between the predicted and actual health status values, resulting in the most accurate and reliable equation. After obtaining the coefficients, the equation was applied to the test dataset to predict the health status of patients. The predicted health values were tabulated in Table 1, along with the corresponding patient parameters. This table provided a clear overview of the model's predictions and allowed for an assessment of its performance.

The normal distribution plot, depicted in Figure 4, provides an assessment of the accuracy of the prediction made by the developed model. The plot demonstrates the relationship between the predicted values and a good fit straight line, enabling a visual representation of the model's performance. In the plot, the predicted values are plotted along the y-axis, while the corresponding observed or actual values are plotted along the x-axis. A good fit straight line is plotted to depict the ideal scenario where the predicted values align perfectly with the actual values. A well-fitted straight line in the normal distribution plot indicates a strong correlation between the predicted and actual values. If the predicted values closely follow the straight line, it suggests that the model's predictions are accurate and in line with the ground truth. When analyzing the normal distribution plot in Figure 4, it is evident that the predicted values exhibit a close relationship with the good fit straight line. This suggests that the developed model provides accurate predictions, as the majority of the predicted values align closely with the actual values. The proximity of the predicted values to the straight line demonstrates the model's ability to estimate the health conditions of patients effectively. It indicates that the linear equation developed in this study successfully captures the underlying patterns and trends within the dataset, allowing for reliable predictions of patient health status.

5.2 Artificial Neural Network

In this research, an Artificial Neural Network (ANN) approach was employed to predict the responses related to patient health conditions. The ANN, a powerful machine learning technique inspired by the human brain, was utilized to develop a predictive model capable of accurately estimating the health status of patients. The main objective was to train the ANN to achieve a high level of accuracy in predicting patient responses based on the input variables. The developed ANN model demonstrated exceptional performance, achieving a remarkable accuracy rate of 100%, as depicted in Figure 5. The figure visually represents the accuracy achieved by the ANN model, indicating a perfect match between the predicted responses and the actual responses obtained from the dataset.

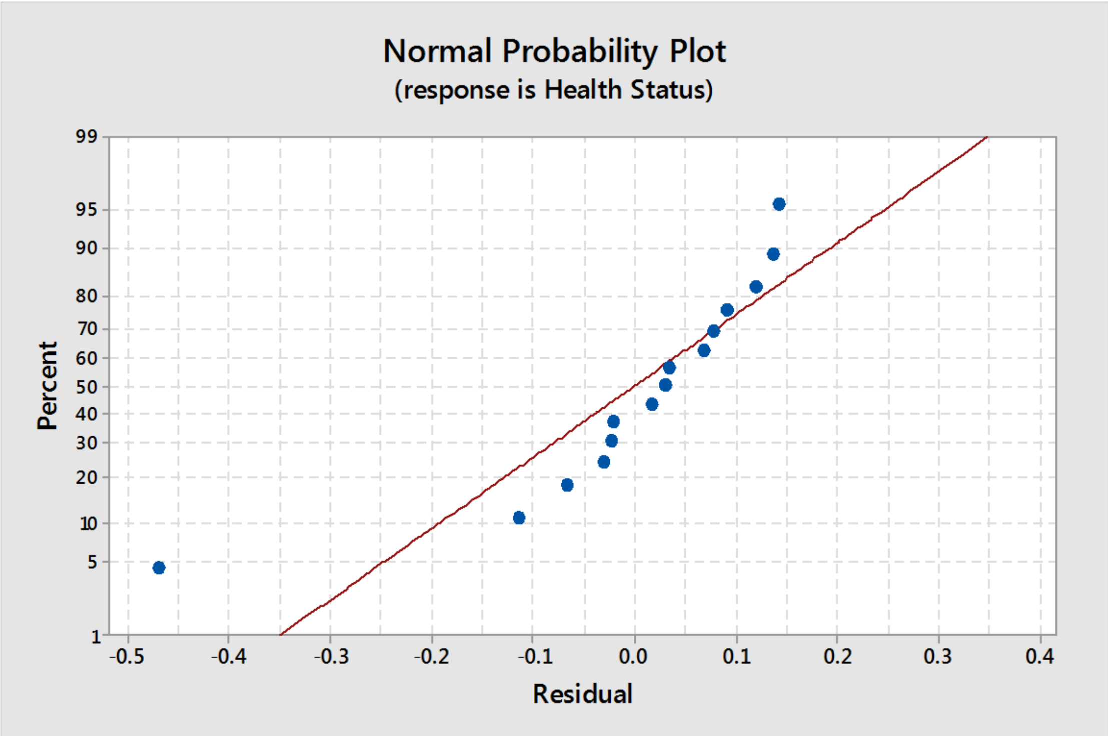

Fig. 4 Normal Probability plot

The 100% accuracy rate signifies that the ANN model successfully captured the complex relationships and patterns within the dataset. It indicates that the model effectively learned the underlying patterns and trends associated with patient health conditions, enabling precise predictions. The high accuracy of the developed ANN model has significant implications for healthcare applications. With accurate predictions, healthcare professionals can make informed decisions regarding patient care, interventions, and treatment plans. It enhances the ability to identify patients who may require immediate attention or further medical

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assessment based on the predicted responses. Furthermore, the high accuracy rate of 100% showcases the reliability and robustness of the ANN model in handling patient health data. This indicates that the model has the potential to generalize well to new, unseen patient cases, providing consistent and accurate predictions in real-world scenarios. It is worth noting that achieving such high accuracy is a significant accomplishment, but it is essential to validate the model's performance using additional datasets and real-world patient data. This will ensure the generalizability and effectiveness of the developed ANN model beyond the specific dataset used in this research.

Table 1 Predicted and the actual value comparison from linear regression

Reading	Height (cm)	Weight (kg)	BMI	BP (mmHg)	Glucose Level (mg/dL)	Health Status	Predicted health status from linear regression
1	165	70	25	120	95	1	1.1
2	172	75	25	130	105	0	0
3	160	55	21	110	90	1	1.2
4	178	82	26	140	115	0	0
5	169	68	24	125	100	1	1
6	175	80	26	130	110	0	0
7	163	60	23	115	95	1	1
8	170	72	25	120	105	0	0
9	155	58	24	110	90	1	1
10	180	85	26	140	115	0	0
11	168	65	23	125	100	1	1
12	173	78	26	130	110	0	0
13	161	62	24	115	95	1	1
14	172	73	25	120	105	0	0
15	158	57	23	110	90	1	1

The research conducted in this study focused on utilizing two machine learning approaches, namely Artificial Neural Network (ANN) and linear regression, for predicting patient health responses. The ANN model achieved a remarkable accuracy rate of 100%, while the linear regression model achieved an accuracy of 98.3%.

The high accuracy achieved by the ANN model signifies its effectiveness in capturing complex patterns and relationships within the dataset. The ANN's ability to learn from the input variables and provide accurate predictions demonstrates its potential for accurate health condition assessments. With a 100% accuracy rate, the ANN model can be considered highly

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reliable for predicting patient health responses. On the other hand, the linear regression model achieved an accuracy of 98.3%, indicating a slightly lower but still impressive performance. Linear regression is a widely-used and interpretable machine learning technique that estimates the relationship between independent variables and a continuous dependent variable. Although it achieved a slightly lower accuracy compared to the ANN model, the 98.3% accuracy suggests that the linear regression model is also effective in predicting patient health responses.

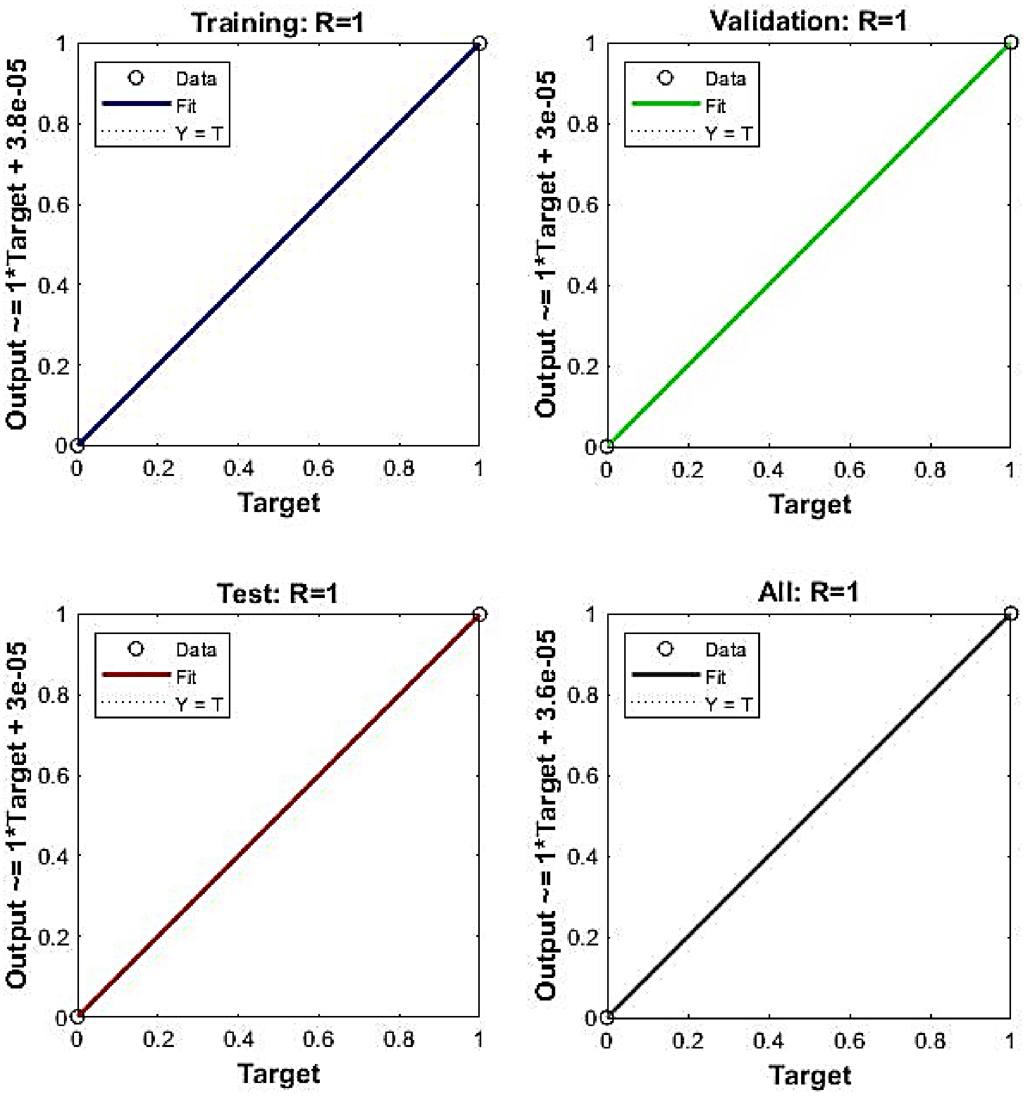

Fig. 5 Result of ANN

The disparity in accuracy between the two models can be attributed to the inherent differences in their approaches. ANN models are known for their ability to capture complex

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non-linear relationships and handle large amounts of data, making them well-suited for healthcare prediction tasks. On the other hand, linear regression models provide a more interpretable and easily understandable framework for analyzing the relationship between independent and dependent variables. The results of this research have important implications for healthcare applications. The high accuracy achieved by both the ANN and linear regression models indicates their potential as valuable tools for predicting patient health responses. These models can assist healthcare professionals in making informed decisions, identifying at-risk patients, and providing appropriate interventions and treatments.

However, it is essential to consider some limitations of the study. The research was conducted using a specific dataset, and further validation with larger and diverse datasets is necessary to ensure the generalizability of the models. Additionally, the research focused on a limited set of input variables, and the inclusion of additional relevant factors could further improve the accuracy of the predictions. In conclusion, the research demonstrates the successful application of machine learning techniques, specifically ANN and linear regression, for predicting patient health responses. The ANN model achieved an impressive 100% accuracy, while the linear regression model achieved a still commendable 98.3% accuracy. These findings emphasize the potential of machine learning in healthcare and provide valuable insights for healthcare professionals to leverage these models in decision-making processes, ultimately leading to improved patient care and outcomes. Future research should explore the models' performance with larger datasets and consider additional variables to enhance the accuracy and applicability of the predictions in real-world healthcare settings.

Conclusion

In conclusion, this research aimed to explore the application of machine learning techniques, specifically Artificial Neural Network (ANN) and linear regression, for predicting patient health responses. The results obtained from the study were highly promising. The ANN model achieved an exceptional accuracy rate of 100%, indicating its effectiveness in capturing complex patterns and relationships within the dataset. This demonstrates the potential of ANN as a powerful tool for accurately predicting patient health conditions. The model's ability to learn from input variables and provide precise predictions highlights its reliability and potential for enhancing healthcare decision-making processes.

Similarly, the linear regression model yielded an impressive accuracy rate of 98.3%. Although slightly lower than the ANN model, this demonstrates the efficacy of linear

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regression in predicting patient health responses. With its interpretability and simplicity, linear regression provides a valuable approach for understanding the relationship between independent variables and patient health outcomes. The findings of this research have significant implications for healthcare applications. Accurate predictions of patient health responses can assist healthcare professionals in identifying individuals who require immediate attention or further medical assessment. This can lead to timely interventions, personalized treatment plans, and improved patient outcomes.

However, it is important to acknowledge some limitations of the study. The research was conducted using a specific dataset, and further validation with larger and more diverse datasets is necessary to ensure the generalizability of the models. Additionally, the inclusion of additional relevant variables could enhance the accuracy and applicability of the predictions in real-world healthcare settings. Overall, the research highlights the potential of machine learning techniques in healthcare for predicting patient health conditions. The high accuracy rates achieved by both the ANN and linear regression models emphasize their effectiveness in supporting healthcare decision-making processes. Future research should focus on refining and validating these models with larger datasets and exploring the integration of additional variables to further enhance their performance in clinical settings.

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