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An Expert System for Insulin Dosage Prediction using Machine Learning & Deep Learning Algorithms

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Abstract—**Diabetes is a long-term metabolic condition. This study describes an expert system for predicting diabetes and insulin dosage. A deep learning approach is used in the proposed system to predict diabetes and a machine learning algorithm is used to predict insulin dosage based on several characteristics like blood sugar levels, body mass, age, insulin, and diabetic pedigree function. A deep learning and machine learning algorithm was trained on a PIMA Indian diabetes dataset& related properties to create the system. To improve the model parameters, the model is trained using a Convolutional Neural Network (CNN) technique. Once trained, the algorithm can accurately calculate insulin dosage. The result reveals that the model exceeds existing insulin dosage prediction systems in terms of accuracy. The proposed approach can potentially improve the accuracy of insulin dosage prediction, reduce the risk of hypoglycemia and hyperglycemia, & ultimately improve the quality of life for diabetic patients.**

Keywords—PIMA Indian diabetes datasets, Convolutional Neural Network, Random Forest Regression.

I. INTRODUCTION

Artificial Intelligence (AI) based techniques for diagnosing diseases are employed in many recent research articles [1&2]. An expert system for insulin dosage prediction is a cutting-edge technique for managing diabetes, a chronic condition that impacts millions of people worldwide. Insulin dosage prediction is critical in diabetes treatment because it includes predicting the ideal quantity of insulin a patient requires to keep blood sugar levels within a normal range. Traditional insulin dosage prediction methods rely on inaccurate and time-consuming manual predictions based on a patient's insulin levels and carbohydrate content. Deep learning, a form of artificial intelligence that simulates the neural networks of the human brain, is a possible alternative to these older methods. The deep learning algorithms used in the system are trained on a large amount of data and can learn patterns and relationships in the data to make accurate predictions. This expert method is designed to forecast future insulin dosage needs by analyzing a patient's past insulin dosage data as well as other essential health information like blood glucose levels, physical activity, and Body mass. This method improves the accuracy and efficiency of insulin dosage prediction.

Deep learning models are trained on large datasets of clinical and physiological information to predict insulin dosage based on a range of factors, such as blood glucose levels, carbohydrate intake, and physical activity. These models use multiple layers of artificial neural networks to learn patterns in the data and make accurate predictions. One advantage of deep learning models is their ability to handle complex and high-dimensional data, which is often present in clinical datasets. Overall, deep learning-based insulin dosage prediction models have the potential to improve diabetes management by providing personalized insulin dosing recommendations to individuals with diabetes, ultimately leading to better health outcomes.

The random forest regression algorithm is a robust machine-learning tool for analyzing and modeling large data sets like medical records and patient histories. It works by first generating several decision trees and then combining them to make a forest. The final prediction is based on the average of all the trees in the forest, and each decision tree in the forest is trained on a different subset of the data. By adding this algorithm into an expert system, healthcare professionals can predict insulin dosages based on patient data such as glucose levels, meal intake, and physical activity. This can result in more accurate dosing, better glucose control, and, ultimately, better patient outcomes.

II. LITERATURE REVIEW

In the paper [1], they used the Naive Bayes classifier to suggest a new strategy for predicting early diabetes. The study used a dataset of 768 instances containing various medical characteristics such as glucose level, blood pressure, insulin, BMI, and so on. Before developing the Naive Bayes classifier, the authors used several pre-processing approaches such as normalization and feature selection on the dataset. The classifier was trained using 10-fold cross-validation, and its performance was assessed using measures, accuracy, precision, and F1 score. According to the study results, the proposed system acquired an accuracy of 77.47%, which is equivalent to the performance of other surface treatments. The authors also performed a feature selection study to find the most important factors that contribute to diabetes prediction. According to the results, the glucose level is an important factor in predicting diabetes.

The paper [2], describes creating ML models for prediction using various clinical and demographic features. The authors used a 768-item dataset with eight input features and one output feature. To create their models, they used a variety of ML algorithms such as KNN, DT, Random forest (RF), SVM, & ANN. They also used feature selection techniques to identify the most pertinent input features for diabetes prediction. The SVM model outperformed other machine learning algorithms, according to the authors, with an accuracy of 80.3% and a sensitivity of 72.5%. Age, BMI, and glucose level were also identified as the most important features for diabetes prediction. However, further studies with larger datasets and more diverse patient populations are needed to validate the results of this study. Additionally, newer techniques and architectures for machine learning have been developed since 2020, which may further improve their performance in predicting diabetes.

In the paper [3], the author used ANN to predict the onset of diabetes. The researchers used a dataset containing 768 patients' medical records, which included demographic and clinical information such as age, BMI, and blood pressure, among other things. The model was trained on 500 data samples and tested on 268 data samples. They trained several ANNs with different architectures and activation functions and compared their results to logistic regression and decision trees. According to the authors, the best-performing ANN achieved an accuracy of 89.4%, outperforming logistic regression and decision trees, which achieved accuracies of 77.6% and 71.2%, respectively. The authors also ran a sensitivity analysis to determine the most important factors for predicting diabetes onset, which included BMI, age, and glucose level.

The paper [4], describes a study that used machine learning algorithms to diagnose diabetes. To train and evaluate the machine learning algorithms, the authors used the PIMA diabetes dataset, which contains information about the medical histories of PIMA women. The model was trained on 538 data samples and tested on 230 samples. The research evaluates the performance of various ML techniques, such as logistic regression, decision trees, RF, SVM, KNN, and ANN. For the PIMA diabetes dataset, the SVM algorithm beats other ML techniques, achieving a classification accuracy of 77.60%. This research shows that ML algorithms have the potential to be a suitable tool for diabetes diagnosis. Additionally, ML algorithms can analyze a larger set of data and potentially identify complex relationships between variables, making them useful for predicting and diagnosing diseases.

The authors of [5], describe ML algorithms to predict insulin levels in diabetes patients. The authors used the PIMA diabetes dataset, which contains information about the medical histories of PIMA women. The model was trained on 500 data samples and tested on 268 data samples. The study evaluates the performance of various machine learning methods in predicting insulin levels in diabetic patients, including linear regression, decision trees, SVM, and ANN. According to the studies, the SVM algorithm beats other machine learning algorithms in forecasting insulin levels in diabetic patients. The study also emphasizes the significance of feature selection in boosting machine learning model performance. This research shows that ML algorithms have the potential to be a suitable tool for diabetes diagnosis.

The paper [6], describes a study on diabetes classification in a big data environment using optimized feedforward neural networks. To train and test the neural network, the author uses the PIMA Indian diabetes dataset, which contains information about the medical histories of PIMA Indian women. The model was trained on 537 data samples and tested on 231 data samples. The research focuses on improving the neural network's performance by obtaining the optimal collection of input characteristics and modifying the hyperparameters. The authors apply the PSO algorithm to optimize the neural network's input characteristics and hyperparameters. For the PIMA Indian diabetes dataset, the improved neural network beats conventional classification algorithms, with a classification accuracy of 83.5%.

In paper [7], The goal of this study was to develop a deep learning model for predicting blood glucose levels in patients with type-1 diabetes using data collected by continuous glucose monitoring (CGM) devices. The researchers aimed to create a model that could be deployed on edge, meaning it could run locally on a device such as a smartphone or wearable device. The study used data from the OhioT1DM dataset, which includes CGM data collected from 16 patients with type 1 diabetes over a period of 2-3 months. The researchers used an LSTM neural network, RNN, to predict blood glucose levels based on previous glucose readings and other features such as insulin dosages and meal times.

In the paper [8], the authors provide background information on diabetes, its prevalence, and its impact on public health. They discuss the importance of early detection and prediction of diabetes, which can help in the prevention and management of disease. The authors also explain the concept of ANN and its potential for prediction and classification tasks. The authors then describe their study, which involved collecting data on various risk factors for diabetes from a sample of 768 patients. They used this data to train an ANN model and then tested its performance in predicting the onset of diabetes in a subset of the sample. The study showed that the result of the ANN model was able to predict the onset of diabetes with an accuracy of 78.64%, which is a significant improvement over traditional statistical methods. The authors also compared the performance of their ANN model with other machine learning models such as SVM and decision trees and found that the ANN model outperformed these models in terms of accuracy.

III. EXISTING SYSTEM

***Gluco-Net**:* It is a deep learning-based system that predicts insulin dosage using a convolutional neural network (CNN). The technology predicts the appropriate insulin dosage for the patient based on blood sugar levels and carbohydrate content. A mobile application is also included in the system, allowing patients to enter their data and view their estimated dosage.

Deep-Diabetes: It is a deep learning-based system that predicts insulin dosage using an RNN. To forecast future insulin needs, the method uses data such as blood sugar levels, insulin dosing history, and carbohydrate content. It also contains a mobile app that allows users to enter their information and see their projected dosage.

A. Limitations of Existing System

- ***Limited Training Data*:** Deep learning systems require a huge quantity of training data to reach high accuracy, but gathering this data can be difficult. Many existing deep learning-based systems for insulin dosage prediction have been trained on short datasets, which may restrict their accuracy.
- ***Lack of personalization*:** While deep learning algorithms are effective tools for evaluating vast amounts of data, they may not always deliver tailored insulin dosage recommendations. Many present systems use generic algorithms that may fail to account for changes in insulin sensitivity and other factors.
- ***Reliance on patient input*:** Some current system needs patients to manually enter data such as blood sugar levels and carbohydrate content, which can be time-consuming and lead to data entry errors.

IV. PROPOSED SYSTEM

In our Proposed Model, we collected the dataset of patient information and then the dataset is uploaded into the system for pre-processing the data to remove the missing and erroneous values. Following that, the dataset is split for testing and training purposes, and the CNN Algorithm is used to predict diabetes for insulin dose prediction, followed by the Random Forest Regression technique.

Advantages:

- ***Improved Accuracy:*** Deep learning models can understand complicated patterns and correlations between patient records and insulin dosages, resulting in more accurate estimates than older methods based on basic heuristics or rules.
- ***Real-time prediction***: Expert systems powered by deep learning can make insulin dosage predictions in real-time, allowing patients to change their insulin dosage depending quickly and efficiently on their current glucose measurements.
- ***Improving Patient Outcomes*:** Expert systems can assist patients to achieve more effective glycaemic control by giving accurate and personalized insulin dosage recommendations, resulting in improved long-term health outcomes and lower healthcare expenditures.
- ***Cost-effective:*** Expert systems can minimize the need for regular visits to medical providers, as well as the fees related to laboratory testing and consults, making insulin management more inexpensive and accessible to patients.

A. System Architecture

We first introduced the diabetic dataset as input to the model. It describes the framework architecture. The System diagram of the proposed system is given below.

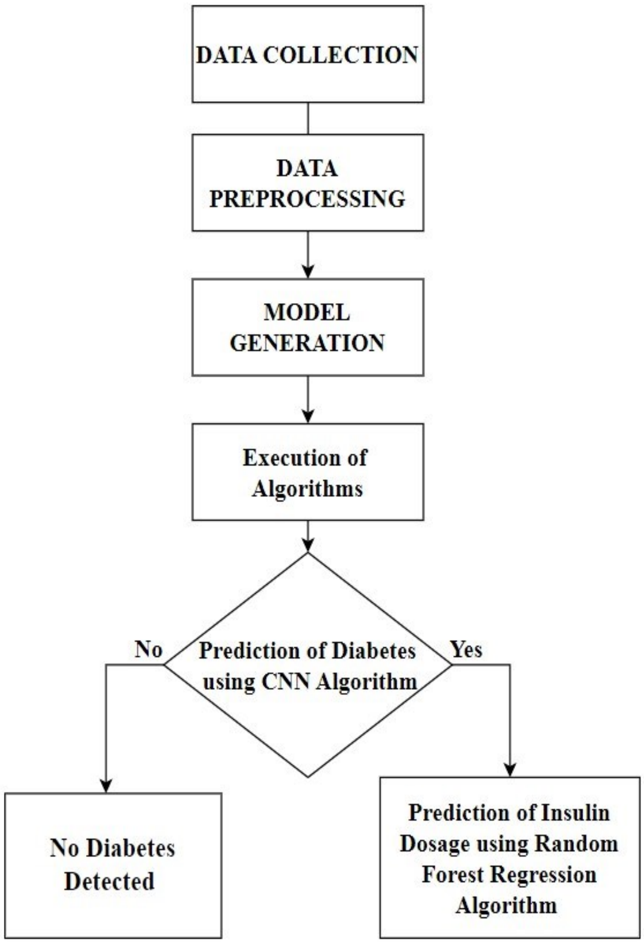

Figure 1: System Architecture

Dataset Collection

The data collection process is performed by determining the variables to collect attributes like body mass index, blood glucose level, and other factors, gathering the data from multiple sources, and cleaning and preprocessing the gathered dataset. All the datasets are taken from Kaggle. The dataset includes 768 patients in total. There are eight characteristics in all, plus a class variable that specifies whether or not a patient has diabetes. The number of pregnancies, dimensionless blood sugar level (2 hours in an oral glucose tolerance evaluation), pulse rate (mm/Hg), skin-fold thickness (mm), insulin Dosage (mm U/ml), BMI (kg/m2), and age is all expressed as numbers. These are the independent variables, and the outcome decides whether a person is healthy or not.

Table 1. Sample Dataset

Pre	Gluc	BP	ST	Ins	BMI	DPF	Age	Oc
2	144	74	25	0	33.6	0.627	50	1
1	85	66	29	0	26.6	0.351	31	0
8	183	64	0	0	23.3	0.672	32	1
1	89	66	23	94	28.1	0.167	21	0
0	137	40	35	163	43.1	2.288	33	1
5	116	74	0	0	25.6	0.201	30	0

Data pre-processing

Using pre-processing methods, the raw data are converted into a set of comprehensible data. To put it another way, anytime information is acquired from several sources in a format that makes analysis impossible. It explains the steps involved in cleaning, transforming, and combining data to prepare it for analysis. Data pre-processing is done to improve the quality of the data. The input features and target variables are separated and normalized using the **normalized** function. Before running the algorithm, the dataset is pre-processed to look for handling missing values, data normalization, data shuffling, reshaping the input data into a 4D tensor, and one-hot encoding of the target variable.

Model Generation

Training data make up 80% and testing data 20%, respectively, of the two datasets that make up the information. First, we must use the proper parameters to train the model on the pre-processed datasets. The model can then be put to the test using test data. Train datasets are typically used to fit deep learning models, and test datasets are typically used to evaluate them. The key goal is to gauge the model's performance with fresh data. When we have enormous datasets, we train and test our models.

Execution of Algorithms

The Artificial Neural Network (ANN) model for diabetes prediction using the Keras library. It reads a diabetes dataset from a CSV file, preprocesses it, and splits it into training and testing sets. Then it builds a sequential ANN model with two hidden layers using the 'relu' activation function and a dropout layer to prevent overfitting. Finally, it trains the model, evaluates its accuracy on the testing set, and outputs the result along with a count plot of the dataset's target variable.

The Convolutional Neural Network (CNN) model for predicting diabetes using the diabetes dataset. It first loads and preprocesses the dataset by filling in missing values, normalizing features, shuffling the dataset, and splitting it into training and testing sets. The CNN algorithm forms two convolutional layers, two pooling layers, and two dense layers to predict diabetes with high accuracy. The CNN algorithm is very efficient and gives higher accuracy.

The Random Forest Regressionmodel normalizes the input data, splits the data into training and testing sets, fits a random forest regression model to the training data, predicts the insulin dosage for the test data, and calculates the accuracy score of the model.

Insulin Dosage Prediction

After detecting diabetes, the Random Forest Regression algorithm predicts the insulin dosage for those who have diabetes. Finally, for each test sample, the corresponding diabetes prediction is obtained from the CNN model and the predicted insulin dosage is printed along with the test values if diabetes is detected.

V. RELATED WORK

Convolutional Neural Network Algorithm:

The architecture based on the CNN is a kind of deep learning technique which is used in diabetic prediction. The dataset would need to be preprocessed and divided into training, validation, and test sets. The CNN model would then be designed and trained on the training set using backpropagation and gradient descent. The model consists of two convolutional layers with 128 and 64 filters respectively and max pooling layers. The output of the second pooling layer is flattened and passed through two fully connected layers with 32 neurons respectively, with the final layer using a softmax activation function to output class probabilities. The performance of the model would be evaluated on the validation set, and the hyperparameters of the model would be tuned to improve its performance. Finally, the performance of the model would be assessed on the test set to determine its accuracy and generalizability. The main reason for choosing the CNN is it depends upon the specific characteristics of the data. It handles the complexity of the data, the size of the data, and the structure of the data.

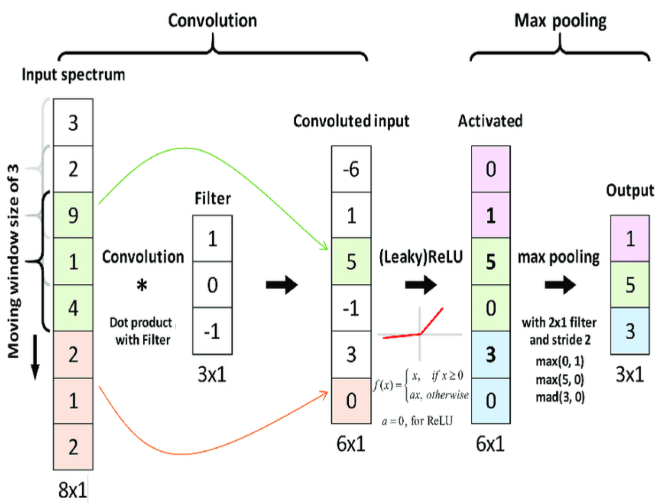

Figure2: Convolutional Neural Network

The first layer added to the model is a Convolution2D layer, which applied a convolution operation to the input data. The layer has 128 filters, a kernel size of (1,1), and an activation function of 'relu'. The next layer is the max pooling2D layer, which reduces the spatial dimensions of the data by taking the maximum value in each pool size (1,1). And again Convolution2D layer has 64 filters and the same kernel size and activation functions as the first layer. And Another maxpooling2D layer follows as first. After this, the flatten layer reshapes the output of the previous layer into a 1D vector, which can be used as input. Then the Dense layer has 32 nodes and an activation function of 'relu'& another dense has a number of nodes equal to the number of classes in the output.

Random Forest Regression Algorithm:

Random Forest Regression is a form of supervised learning method that makes predictions by combining numerous decision trees. It is used to describe the link between patient-specific data such as glucose levels, insulin dosages, and other important parameters in insulin dosage prediction. Based on current and historical data, the model can then be used to estimate future insulin dosages. Random forest regression has various advantages for predicting insulin dosage, including the capacity to handle both numerical and categorical data, capture non-linear correlations in the data, and handle missing data. Random forest regression also supports feature importance analysis, which can reveal the most essential elements that influence insulin dosage prediction.

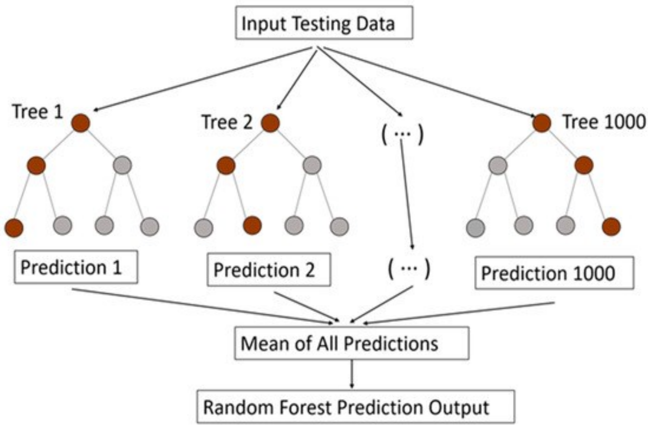

Figure3: Random Forest Regression

In a Random Forest regression model, the data is split into multiple decision trees, and the final prediction is a combination of the predictions of all the trees. The features are randomly sampled, and each decision tree is trained on a subset of the data. The depth of each tree is controlled using the max_depth hyperparameter. Overall, the use of the Random Forest Regression algorithm in an expert system for insulin dosage prediction can be effective in creating a more accurate and personalized prediction model.

VI. RESULT ANALYSIS

The proposed model result is the level of intensity recognized from diabetes patients after different approaches using Deep Learning and ML algorithms. The Proposed System detected whether the patient has diabetes or not and also predicted insulin dosage for those patients who have diabetes. And the proposed system gave an accurate result using CNN Algorithm. The system achieved high accuracy rates in predicting insulin dosages and the system's accuracy depends on the dataset used for training and testing the model. The proposed System gave 73% accuracy for ANN Algorithm, 66% accuracy for Random Forest Regression Algorithm, & 85% accuracy for CNN Algorithm.

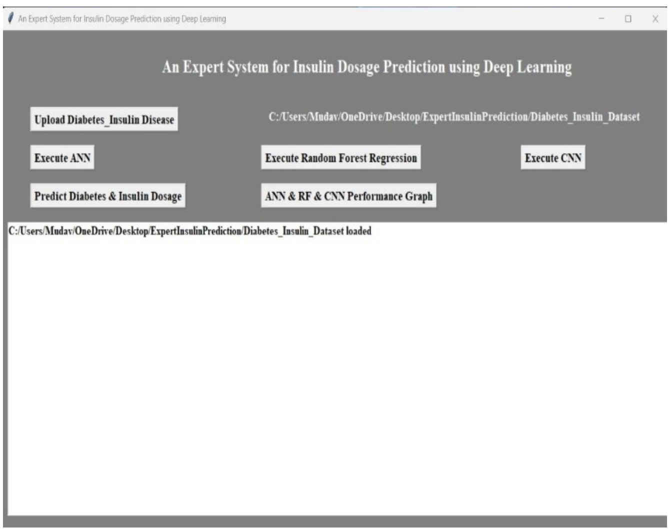

Figure 4: The above figure displays that all the datasets are loaded successfully.

```
Test Values : [0.05688306 0.50057095 0.70534997 0.         0.         0.28441531
 0.00667807 0.40955805] ==== Diabetes Not Predicted

Test Values : [0.00975776 0.68792235 0.28297515 0.16588199 0.62449688 0.1239236
 0.00341034 0.11709317] ==== Diabetes Not Predicted

Test Values : [0.03261521 0.90390731 0.31683349 0.13046085 0.         0.16726945
 0.00347119 0.19103196] ==== Diabetes Detected & Predicted Insulin Dosage : 192

Test Values : [0.01489997 0.33711187 0.12664976 0.06704987 0.92193576 0.05606114
 0.00114544 0.11174979] ==== Diabetes Not Predicted

Test Values : [0.02458621 0.63572924 0.29503456 0.07375864 0.67436472 0.12609215
 0.00205822 0.17912813] ==== Diabetes Not Predicted

Test Values : [0.         0.85977959 0.43229141 0.12968742 0.         0.21182279
 0.00329502 0.11047447] ==== Diabetes Not Predicted

Test Values : [1.11296402e-02 4.11796687e-01 1.66944603e-01 7.51250713e-02
 8.84806395e-01 8.59764705e-02 4.17361507e-04 8.06898914e-02] ==== Diabetes Not Predicted
```

Figure 5:The figure shows the detection of Diabetes and Insulin Dosage with the test values.

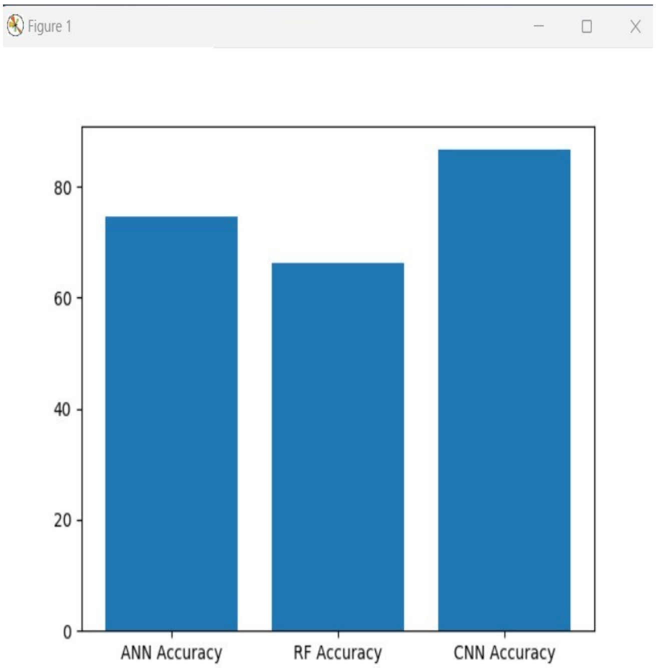

Figure6: The above figure shows the performance graph of the algorithms.

VII. CONCLUSION

This paper aimed to construct neural networks for predicting the optimum insulin dosage for diabetic patients. The model was created using CNN and trained using BP. Four pieces of patient-specific variables are required by the model: length, weight, blood sugar, and gender. Numerous studies made use of the data from 180 patients. Convolutional Neural Networks are used to predict diabetes. If the CNN algorithm detects diabetes, the Random Forest Regression approach estimates insulin dosage. The CNN model gave results that were both performant and quickly converged.

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