# A Single Layer Perceptron-based Approach for Diabetes Data Classification

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## Abstract

*Diabetes is one of the leading causes of morbidity and mortality worldwide. Diagnosis of diabetes is a crucial step in the treatment of diabetes. In this study, we introduce an approach based on perceptron, for categorizing diabetes data by harnessing the capabilities of neural networks to enhance accuracy and efficiency. The dataset comprises of 768 women with age of more than 21 years. We leveraged the model to perform training and evaluating it on different learning rates. We achieved an accuracy rate of 80.8%, with an ideal learning rate of 0.05.*

## 1. Introduction

Diabetes is a long-term condition that impacts individuals across the globe [14]). Precise categorization of diabetes information plays a role, in identifying it making diagnoses and devising effective treatment strategies [17]. Over the years the application of machine learning methods has demonstrated encouraging outcomes in analyzing medical data particularly when it comes to classifying diabetes. Algorithms such as Random Forest, Logistic Regression and Artificial Neural Network (Multilayer Perceptron) were used to achieve a accuracy level of 76.1, 74.75 and 77.1 % by Darolia and Chhillar [3], Patra and Khuntia utilized Modified K-Nearest Neighbour classifier to achieve accuracy of 83% where they leveraged a new distance calculation formula using standard deviation[18]. Hama Saeed examined performance of Extra Tree, Decision Tree, AdaBoost & Gradient Boosting Classifier with accuracy 89, 81, 77 and 84 percentages respectively, with the help of upsampling technique for balancing of dataset [8], Rajni and Amandeep used RB(Recursive Bayesian) Bayes algorithm for Binary Classification and attained an accuracy of 78.9 % [21]. We refer these studies and utilize the pre-processing techniques, evaluation metrics and inculcate them in our study, we introduce an approach based on single layer perceptron, for categorizing diabetes data by harnessing the capabilities of artificial neural networks.

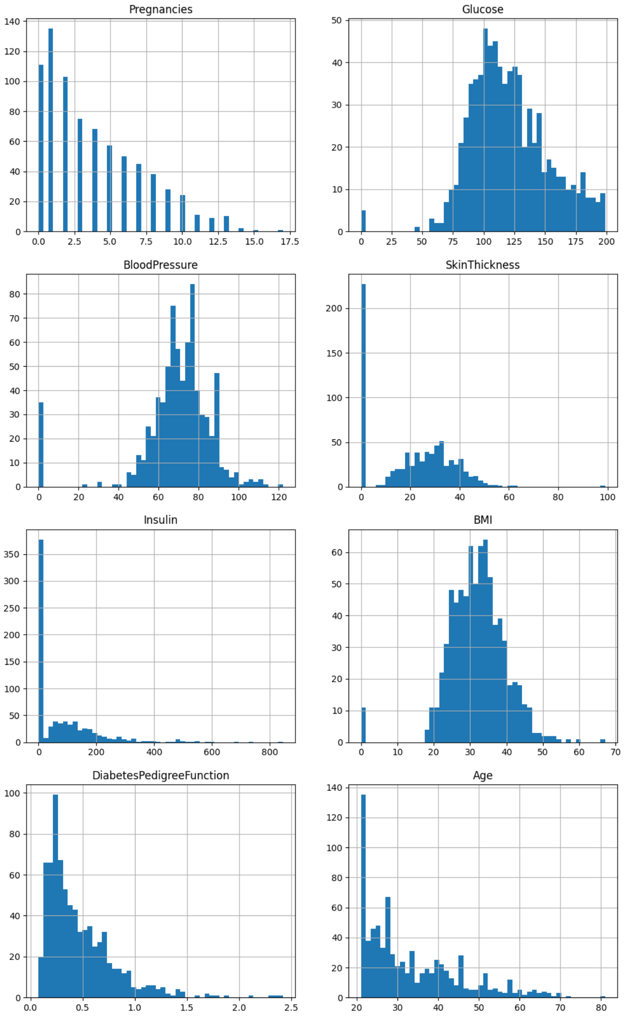

Figure 1. A histogram for each numerical attribute

## 2. Method

In this section we will delve into the materials and methods utilized in the research study. Subsequently we will provide a breakdown of the dataset, methods and approach, in subsequent subsections.

| Sr. No. | Selected Attributes from PIDD | Description of selected attributes | Range | Attribute Type | Data Type |
|---|---|---|---|---|---|
| 1 | Pregnancies | Number of times a participant is pregnant | 0-17 | Feature | Numerical |
| 2 | Glucose | Plasma glucose concentration a 2 hours in an oral glucose tolerance test | 0-199 | Feature | Numerical |
| 3 | Blood Pressure | It consists of Diastolic blood pressure (when blood exerts into arteries between heart)(mm Hg) | 0-122 | Feature | Numerical |
| 4 | Skin Thickness | Triceps skinfold thickness (mm). It is concluded by the collagen content | 0-99 | Feature | Numerical |
| 5 | Insulin | 2-Hour serum insulin (mu U/ml) | 0-846 | Feature | Numerical |
| 6 | BMI | Body mass index | 0-67.1 | Feature | Numerical |
| 7 | Diabetes Pedigree Function | Synthesis of the diabetes mellitus history in relatives and the genetic relationship of those relatives to the subject[24] | 0.078-2.42 | Feature | Numerical |
| 8 | Age | Age of participant | 21-81 | Feature | Numerical |
| 9 | Outcome | Diabetes class variable, Yes represent the patient is diabetic and no represent patient is not diabetic | Yes/No | Target | Categorical |

Table 1. Description of all PIDD attributes

### 2.1. Dataset

The dataset utilized in this research corresponds to the Pima Indian community situated near Phoenix, Arizona, a dataset that has been continuously examined since 1965 by the National Institute of Diabetes and Digestive and Kidney Diseases [24]

PIMA Indian diabetes dataset (PIDD) consists of 9 attributes, 8 predictors and 1 class label. The dataset comprises of 768 women with age of more than 21 years. Above depicted are histogram plots and table with description and for each of attribute(s) of PIDD [16]

### 2.2. Single-Layer Perceptron (SLP)

The Single-Layer-Perceptron is the most basic Artificial Neural Network architectures, the model was invented by Frank Rosenblat [22]

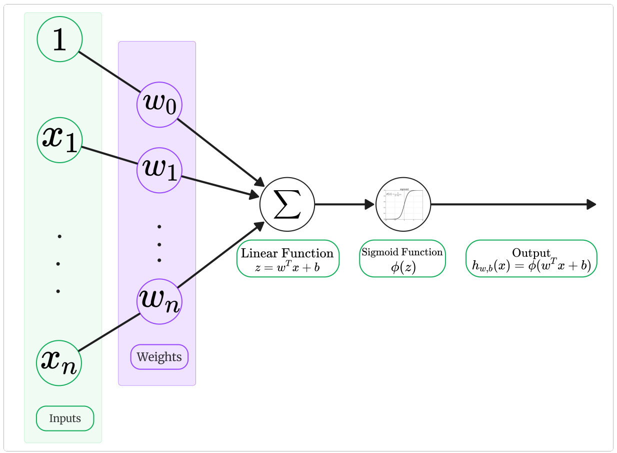

Figure 2. The Components of Single Layer Perceptron

A Perceptron can be described as a linear threshold device that computes weighted sum of the coordinates of the pattern vector, compares the value with a threshold, and outputs +1 or -1 if the threshold is reached, threshold is identified as the activation function that we employ [23]. The below diagram depicts the concept [7]. SLP even though being the most elementary form of ANN still find use in multitude of fields of study, Alkhamees utilized optimized SLP for classification in context of fetal state detection [1], SLP to analyze laboratory data [5], for prediction of Bankruptcy [11], and data security [15]. The core formula behind SLP

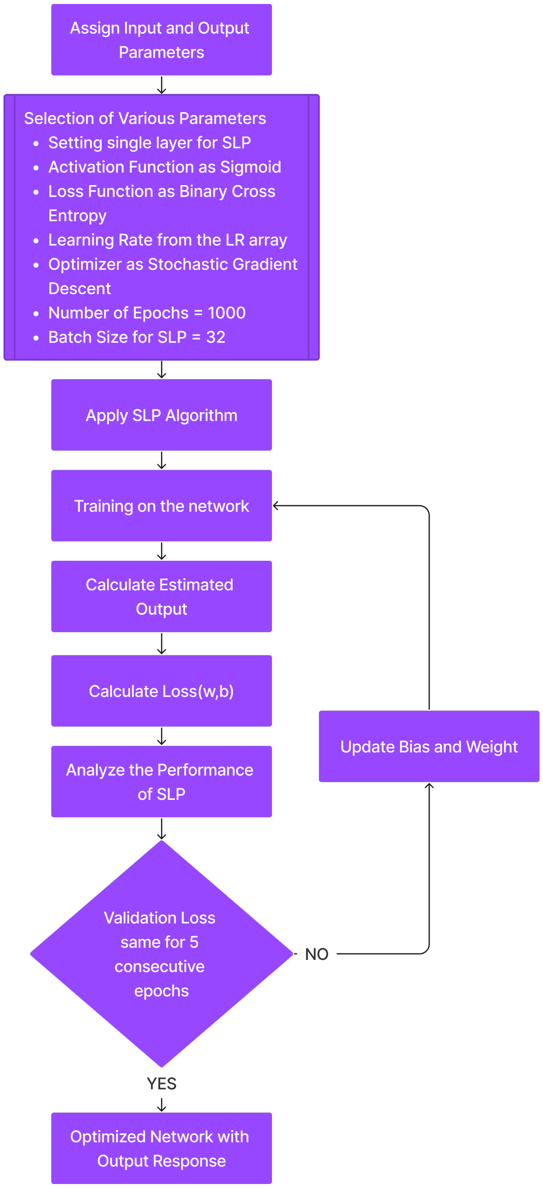
Assign Input and Output Parameters
Selection of Various Parameters
• Setting single layer for SLP
• Activation Function as Sigmoid
• Loss Function as Binary Cross Entropy
• Learning Rate from the LR array
• Optimizer as Stochastic Gradient Descent
• Number of Epochs = 1000
• Batch Size for SLP = 32
Apply SLP Algorithm
Training on the network
Calculate Estimated Output
Calculate Loss(w,b)
Analyze the Performance of SLP
Update Bias and Weight
Validation Loss same for 5 consecutive epochs
NO
YES
Optimized Network with Output Response

Figure 3. Flowchart for SLP Training

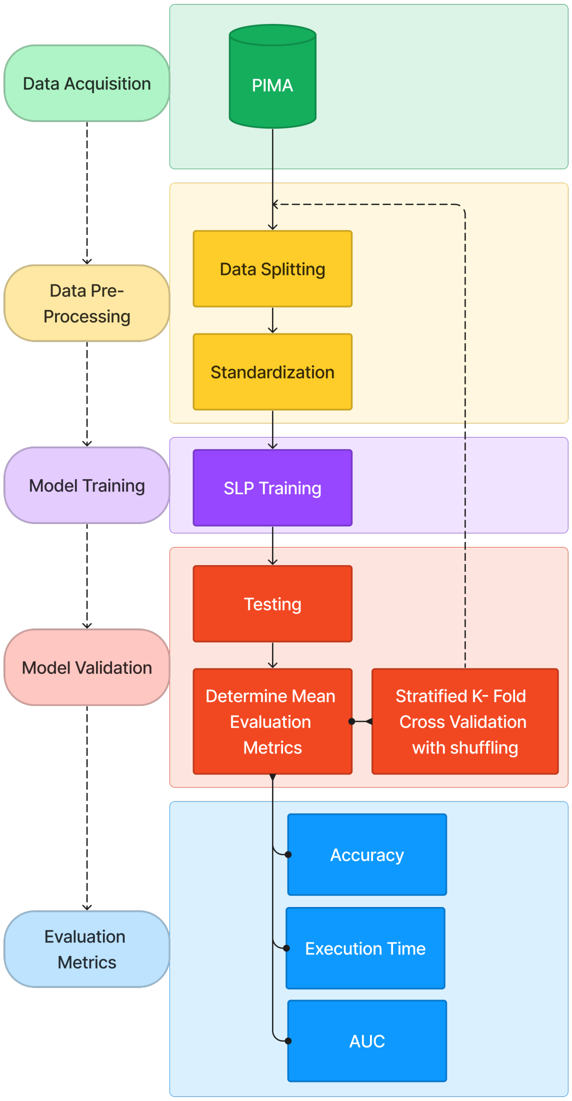

Figure 4. Flowchart for ML Pipeline

is

$$z = w_0\mathrm{i} + w_1x_1 + w_2x_2 + ... + w_nx_s$$

As is depicted in Figure : 2, The inputs $x_0, x_1, ...x_n$ are multiplied with the individual weights $1, w_1, x_2, ...x_n$, further down the line they are summed up. Then the weighted sums are pass through a step function also known as activation function or transfer function, which as described below.

$$\phi(z) = \frac{1}{1 + \exp{-z}}$$

In order to simplify the calculation and reduce the processing delay, we employ the Sigmoid activation function a nonlinear activation function to provide clear probabilistic outputs, enabling straightforward interpretation for the binary classification. The next part involves training and updating of the weights, given by the equation below.

$$w_i{}^{\text{next step}} = w_i + \eta \left(y_i - \hat{y}_i\right) x_i$$

If training instances are linearly separable, Rosenblatt demonstrated that this algorithm would converge to a solution. This is called the perceptron convergence theorem[22]. We use multiple values of learning rate(s) $(\eta)$ for our analysis, in order to determine the best rate for training our model . As depicted above is the flowchart Figure: 3 for the Algorithm with respect to implementation in the code for PIDD.

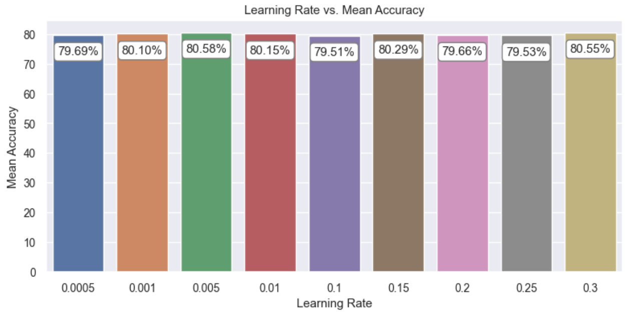

Figure 5. Mean Accuracies of SLP Model at different Learning Rate

## 2.3. Model Pipeline

The representative pipeline for the Training of the SLP Algorithm. The PID Dataset for this project is downloaded from online Platform Kaggle [13]. The data is split and standardized [4]. Further in the pipeline we train our SLP model as is described in Figure : 4, with Binary Cross Entropy to calculate the loss and Stochastic gradient descent as the optimizer. We set an epoch limit of 1000 but along with that we implement an early stopping call-back [20]), which would stop the model training if the validation loss tends to remain unchanged for 5 consecutive epochs.

## 2.4. Experimental Analysis

We evaluate the SLP Output using five-fold cross-validation method [6]), we divide the dataset into k=5 partitions with shuffling, one of these set is used for testing, other 4 are used for training. The outcome of each fold is used to compute mean metrics for evaluation.

We evaluate the model using metrics such as accuracy, Execution time, AUC Score

$$Accuracy = \frac{TP + TN}{TP + FP + TN + FN}$$

In the above equation TP = True Positive, TN = True Negative, FP = False Positive, FN = False Negative. TP (TN) represents the number of observations in the positive (negative) class that are classified as positive (negative), and FP (FN) represents the number of observations in the negative (positive) class that are classified as positive (negative).

We train the SLP model with a 5-fold cross validation technique and it trains based on the learning rates which are 0.0005, 0.001, 0.005, 0.01, 0.1, 0.15, 0.2, 0.25, 0.35. The below graph in Figure 5, depicts that there is minor deviation in term of accuracy and the highest being 80.78 % which is obtained by 0.2 learning rate. We use the maximum mean accuracy but summing up the standard deviation of k-fold accuracy(s). Area Under the Curve (AUC) Score is an indicator of the ability of classifier to distinguish between different classes [9]. It represents the area under the ROC curve, a graph where True positive rate is traced by the probabilities curve to different thresholds against the False positive rate. A higher value would imply better model performance. As per Figure 6, we can observe that the AUC score of approximately 0.83 across different Learning rates.

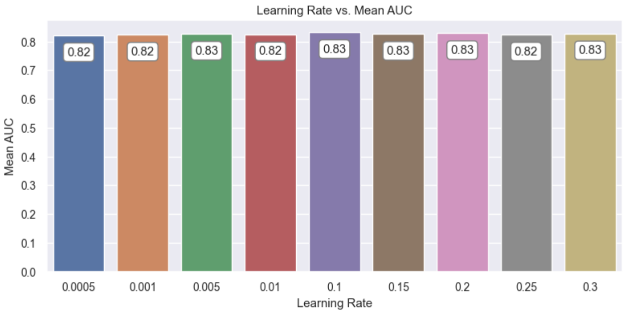

Figure 6. Mean AUC Score at different Learning Rates

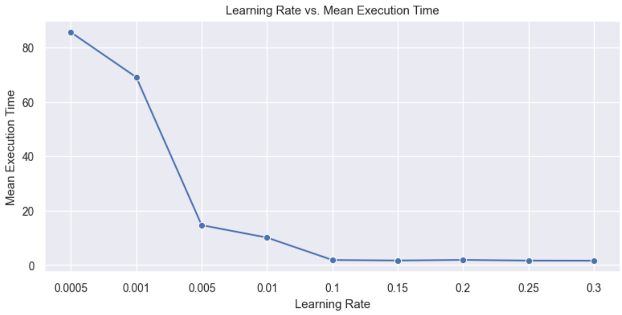

Figure 7. Execution Times for different learning rates

Execution Time represents the amount of time taken by CPU to train the algorithm for each fold, we then take mean execution time. A lower Execution time translates to lesser resources will be used by the algorithm.

As is evident from Figure 7, there is a reduction in Execution time as we increase the Learning rate up-till 0.1 after which the reduction in execution time is minimal. Though one must also note that the stopping condition of training of our algorithm pertains to Early stopping callback function, for which there is a condition of patience level of 5.

## 2.5. Conclusion and Future Work

This research is intended to determine the performance metrics of Single Layer Perceptron in classifying if the patient is diabetic or not. We used five-fold cross-validation into training and test sets to obtain mean values of evaluation metrics owing to the size of dataset which does not warrant the use of larger data splitting. We leveraged the model to perform training and evaluating it on different learning rates, based on that we achieved an accuracy rate of 80.58%, a learning rate of 0.005 would be ideal for further research. There is scope of achieving a higher accuracy if a more complex artificial neural network model is used for this dataset. The need for a larger dataset with balanced values for outcomes would be beneficial.

### 2.6. Code

My code and data is available at `https://github.com/aditya-524/DL_Ass1/blob/main/SLP_PIMA_BinaryClassification.ipynb` The code utilizes the python packages as such matplotlib [12] & seaborn [25], pandas [26], numpy [10], scikit-learn [19], Keras [2].

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