SAI UNIVERSITY

MACHINE LEARNING

COURSE PROJECT REPORT

(PHASE - 1)

TITLE OF THE PROJECT: STUDENT PERFORMANCE

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ML CATEGORY: REGRESSION

1) <u>INTRODUCTION:</u>

The main goal of this problem is to predict the G3 (final year grade) values of students in secondary education of two Portuguese schools. We are asked to predict the G3 values using the given information like the student's demographics, their social and background-related information, previous grades and information related to their school. Using different machine learning models, the values of G3 are predicted and the accuracy scores of the models are compared.

2) <u>DATASET AND FEATURES:</u>

The student performance dataset contains two distinct datasets in it. One dataset is the student performance in maths course and other is the student performance in Portuguese course. Out of the two datasets, I chose the maths course dataset for the project.

The dataset has 33 features(including the target variable G3) and 395 samples in it. Out of those 33 features, 17 are non-numeric and the rest other are numeric. The dataset does not have any missing values in it. The features of this dataset includes attributes like the student's personal information, family information, interests & hobbies, extra-curricular activities, health, previous grades and their social and background information. From the correlation matrix we come to know that the target variable G3 has a high correlation with the previous grades G1 and G2.

3) METHODS:

Before performing any experiment, the input attributes are stored in X and the target variable(G3) is stored in y. The dataset is split into 75% training and 25% testing. Relevant feature scaling is performed on the data for models to make better predictions.

All the experiments are performed using the default settings of the Scikit-Learn library to produce baseline results.

After performing each experiment, to evaluate and to determine the accuracy of the regression model we compute the R^2 score.

The R^2 score is given by:

$$R^2 = 1 - \frac{SS_{res}}{SS_{tot}}$$

$$SS_{res} = \sum_{i}^{n}(y_i - f(x_i))^2 \quad \text{sum of squares explained by model}$$

$$SS_{tot} = \sum_{i=1}^{n}(y_i - \bar{y})^2 \quad \text{sum of squares around the mean}$$

3.1) LINEAR REGRESSION:

Linear regression is a supervised machine learning model which is used to predict a feature (target variable) based on other features in the dataset by drawing a linear relationship between the target variable and other features. This machine learning model represents a linear relationship between the dependent and independent variables to make predictions.

There are two types of Linear Regression models:

- Univariate: In this type of linear regression model only one feature is used to predict the target variable.

The equation is given by:

$$\hat{y} = \theta_0 + \theta_1 x$$

- Multivariate: In this type of linear regression model more than one feature is used to predict the target variable.

The equation is given by:

$$\hat{y} = \theta_0 + \theta_1 x_1 + \theta_2 x_2 + \ldots + \theta_n x_n$$

In our case, the model is a multivariate linear regression since more than one feature is used to predict the target variable G3.

The cost function for linear regression is the mean squared error function. The equation is given by:

$$\mathrm{MSE}\left(\mathbf{X}, h_{\boldsymbol{\theta}}\right) = \frac{1}{m}\sum_{i=1}^{m}\left(\boldsymbol{\theta}^T \mathbf{x}^{(i)} - y^{(i)}\right)^2$$

R^2 SCORE: 0.801706

3.2) SUPPORT VECTOR MACHINES (SVM):

Support Vector Machines (SVM) are robust machine learning algorithms which can perform both regression and classification on linear and non linear data. The SVM finds the optimal hyperplanes to perform regression and classification tasks. In our case, the SVM is used to perform regression. Feature scaling is more important in the context of Support Vector Machines.

There are 3 types of kernels in SVMs (RBF,linear,polynomial).

- SVM(Linear) is used when the data is linearly separable.
- SVM(polynomial) is used when the data is non linear.
- SVM(RBF) also known as Gaussian kernel,creates a non linear combinations of original features and projects them onto higher dimensional space so that data becomes separable by a hyperplane.

R^2 SCORE (RBF) : 0.634897

R^2 SCORE (LINEAR) : 0.80191

R^2 SCORE (POLYNOMIAL) : 0.487093

3.3) DECISION TREES:

Decision Trees are non parametric based machine learning algorithms that are capable of performing both regression and classification. The model represents a tree like structure, where it is used to predict the class in case of classification problem or is used to predict value in case of regression problem. The decision trees are trained using the CART(Classification and Regression Tree) algorithm. Feature scaling is not necessary in the context of Decision Trees.

CART Algorithm:

- The training data is splitted into 2 subsets based on a single feature k and threshold value t_k.
- The pair (k,t_k) is chosen in such a way that it produces a pure subset.
- This process is recursively repeated until max_depth is reached or there is no further split possible.

The cost function of CART algorithm for classification is given by:

$$J(k, t_k) = \frac{m_{\text{left}}}{m} G_{\text{left}} + \frac{m_{\text{right}}}{m} G_{\text{right}}$$

$$\text{where} \begin{cases} G_{\text{left/right}} \text{ measures the impurity of the left/right subset,} \\ m_{\text{left/right}} \text{ is the number of instances in the left/right subset.} \end{cases}$$

The cost function of CART algorithm for regression is given by:

$$J(k, t_k) = \frac{m_{\text{left}}}{m} \text{MSE}_{\text{left}} + \frac{m_{\text{right}}}{m} \text{MSE}_{\text{right}} \quad \text{where} \begin{cases} \text{MSE}_{\text{node}} = \sum_{i \in \text{node}} \left(\hat{y}_{\text{node}} - y^{(i)} \right)^2 \\ \hat{y}_{\text{node}} = \frac{1}{m_{\text{node}}} \sum_{i \in \text{node}} y^{(i)} \end{cases}$$

The cart algorithm tries to reduce the Gini impurity in case of classification problem and tries to reduce the MSE function in case of regression problem.

R^2 SCORE: 0.806642

3.4) RANDOM FOREST:

Random Forest is a powerful ensemble learning method which is a group of decision trees. It aggregates the prediction of each decision tree to yield the final prediction. This machine learning model uses bagging technique to train data. The model is used for performing both classification and regression tasks. In the case of classification, the final prediction of the model is based on the mode of classes. While in the case of regression, the final prediction of the model is based on the mean of the classes. In our case, the model is used for regression.

R^2 SCORE: 0.875369

3.5) ADA BOOST:

Ada Boost is an ensemble learning method which combines several weak learners to obtain a strong learner. In Ada Boost the predictors are trained sequentially. At each iteration, a new predictor is created to correct its predecessor's underfitted instances. The model assigns higher weights to the underfitted instances thereby making the new predictor to focus more and more on hard cases. This helps in improving the accuracy of the model.

R^2 SCORE: 0.862255

3.6) GRADIENT BOOSTING:

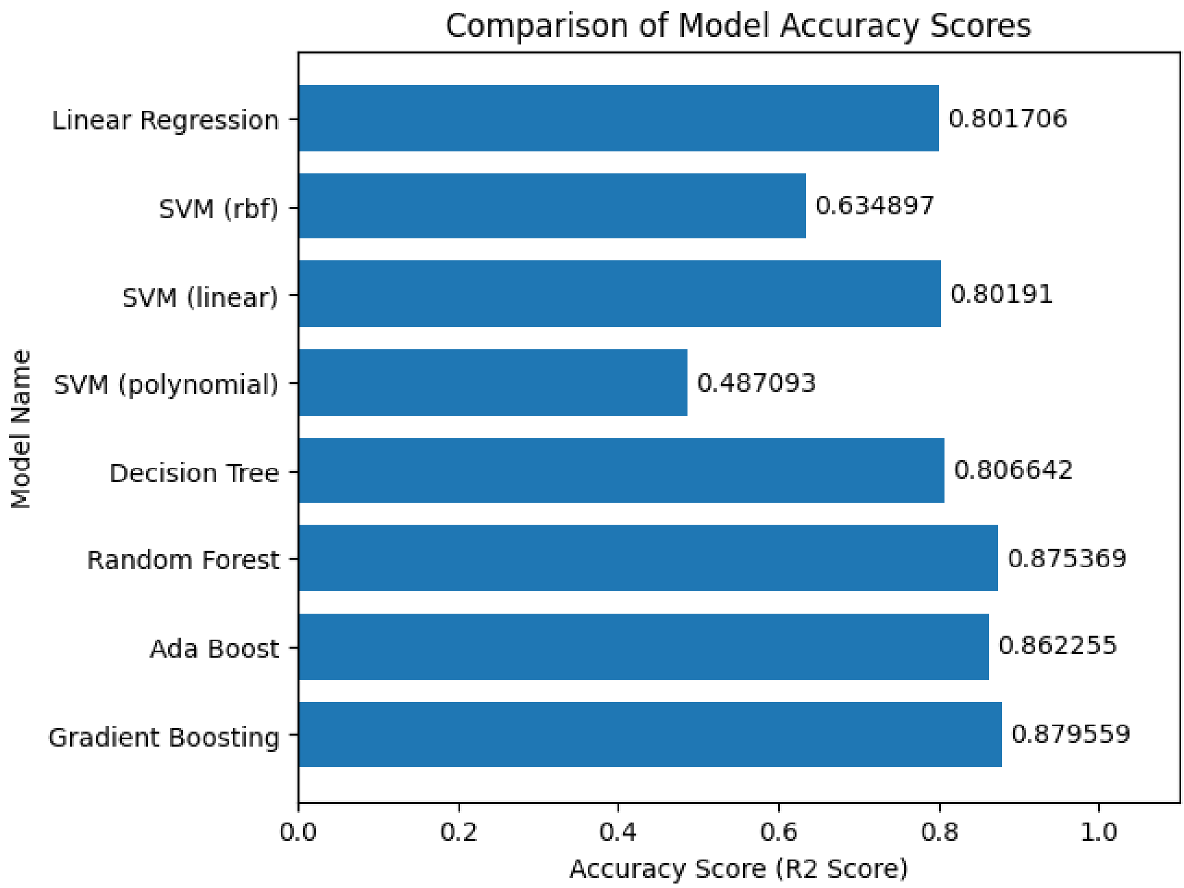
Gradient Boosting is also an ensemble learning method which combines several weak learners to get a strong learner. The model works by sequentially adding predictors based on the residual error. At each iteration, a new predictor is created to correct the residual errors made by the previous predictor. The model reduces the residual error at each iteration thereby minimizing the overall residual error and improving the model's accuracy.

R^2 SCORE: 0.879559

4) RESULTS:

The table below represents the tabular layout of the of the Accuracy scores (R2 score) of different machine learning models.

Model Name	Accuracy Score (R2 Score)
Linear Regression	0.8017064030489103
SVM (rbf)	0.6348965718699183
SVM (linear)	0.801910267728134
SVM (polynomial)	0.4870928019688143
Decision Tree	0.8066423377060506
Random Forest	0.8753690168915028
Ada Boost	0.8622548299472821
Gradient Boosting	0.8795592243811429



The graph above represents the visualization of Accuracy Scores (R2 Score) of different machine learning models.

From the above results, we can conclude that Gradient Boosting has the highest accuracy score when compared to other regression models. Subsequently to that, Random Forest and Ada Boost have the second and third highest accuracy scores respectively. Among all the models, SVM (polynomial) has the least accuracy score.

CITATIONS:

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