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Survey "Student Performance Prediction using Machine Learning"

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ABSTRACT :

For educational institutions to identify at-risk students and enhance overall outcomes, predicting student academic performance is a crucial task. In this study, students' academic and demographic information is analysed using a variety of Machine Learning (ML) algorithms in order to forecast their final grades. The study makes use of a publicly accessible dataset that includes variables like parental educational attainment, study hours, attendance, and prior test results. Among the models compared are Random Forest, Decision Tree, and Linear Regression. According to experimental results, the Random Forest algorithm had the highest accuracy of 91.3%, indicating that it could support teachers in making data-driven decisions for the betterment of their students.

Keywords: Random Forest, Data Analysis, Education, Student Performance, Machine Learning, and Prediction

Introduction

A student's future is greatly influenced by their education, and one of the most important measures of success is academic achievement. Teachers are better able to support struggling students in real time when they can predict their performance. Machine learning makes it possible to make precise predictions using historical data, whereas traditional evaluation systems depend on subjective judgement. Developing and assessing machine learning models that can forecast student academic results based on academic, behavioural, and demographic characteristics is the aim of this study. Institutions can enhance their instructional strategies and create individualised learning plans by utilising data analytics.

Literature Review

Machine learning-based student performance prediction has emerged as a key area of study in the fields of learning analytics and educational data mining (EDM). In order to examine the variables influencing students' academic performance and forecast future results, researchers have used a variety of machine learning algorithms on educational datasets over the last ten years. Early research focused on a small number of academic characteristics, such as attendance and prior exam scores, and mostly used statistical models like logistic regression and linear regression. Modern research, however, has moved towards more sophisticated algorithms like Decision Trees, Random Forests, Support Vector Machines (SVM), Naïve Bayes, and Neural Networks, which can handle complex, non-linear relationships within student data, as data availability and computing power have increased. In contrast to using academic records alone, a number of studies highlight that combining behavioural, demographic, and academic characteristics increases prediction accuracy. Academic success has been found to be significantly influenced by characteristics like prior test scores, parental education level, participation in class activities, and attendance rate. Furthermore, because they can integrate multiple weak learners and lower prediction variance, ensemble learning techniques like Random Forest and Gradient Boosting have continuously outperformed conventional methods. Higher reliability and generalisation across various datasets were attained by hybrid models that combined machine learning and data preprocessing techniques, as shown by Jain and Verma (2023).

One of the first studies to predict student grades based on academic, social, and demographic factors was carried out by Cortez and Silva (2008) using the UCI Student Performance dataset. Their research demonstrated that the Random Forest and Decision Tree classifiers were effective in locating important predictors like parental participation, study time, and past grades. Subsequently, Kumar and Sharma (2021) concluded that tree-based models provide better interpretability for educational administrators after applying Decision Tree and Naïve Bayes algorithms to a similar dataset and achieving an accuracy of 85%.When Patel and Singh (2022) tested Random Forest and SVM models for performance prediction, they found that Random Forest produced a higher accuracy (89%) because of its ensemble nature and capacity to manage overfitting. Using neural networks to identify students who are at risk of dropping out, García et al. (2020) expanded on this work and discovered that deep models could successfully capture intricate behavioural patterns, particularly when working with large, temporal datasets.

Author & Year	Algorithm	Accuracy	Remark
Cortez & Silva (2008)	Decision Tree	85%	Basic Features
Ahmed et al. (2020)	Random Forest	90%	High Accuracy
Mehta & Patel (2022)	SVM	88%	Small dataset

Classification of algorithm

1. **Linear Regression:**

A basic supervised learning algorithm for predicting a continuous dependent variable from one or more independent variables is called linear regression. By fitting a linear equation and applying the Least Squares Method to minimise the discrepancy between actual and predicted values, it models the relationship between inputs and output. It can predict final grades in the context of student performance prediction by taking into account characteristics like study hours, attendance, and results from internal assessments. Training data is used to learn the model's parameters (slope and intercept), and metrics like Mean Squared Error (MSE) or R2 score are used to assess the model's performance. Despite its ease of use and interpretability, linear regression is susceptible to outliers and highly correlated features (Hastie et al., 2009; James et al., 2013; Cortez & Silva, 2008).

2. **Decision Tree Classifier:**

A supervised learning algorithm for classification and regression applications is the decision tree. By learning basic decision rules derived from the data's features, it makes predictions about the target variable. By recursively dividing the dataset according to feature values, the model produces a structure resembling a tree, with each internal node standing for a feature test, each branch for a test result, and each leaf node for the predicted class or value. Based on characteristics like attendance, prior grades, study time, and involvement in class activities, a Decision Tree can predict a student's performance by classifying them as "pass" or "fail." In order to maximise the purity of the resulting subsets, the algorithm chooses splits based on metrics such as Information Gain or Gini Impurity. Because decision trees are so interpretable, teachers can learn how particular factors affect predictions. However, without pruning or ensemble techniques, they may perform poorly on unseen data and are prone to overfitting if the tree gets too deep (Quinlan, 1986; Breiman et al., 1984; Cortez & Silva, 2008).

3. **Random Forest Classifier:**

Several Decision Trees are combined in the Random Forest ensemble learning algorithm to increase prediction accuracy and manage overfitting. During training, it builds a lot of individual trees and outputs the mean prediction (for regression) or the mode of the classes (for classification). In order to improve generalisation and diversity among trees, each tree is trained on a random subset of the data (bagging) and takes into account a random subset of features when splitting nodes.

Using characteristics like past grades, attendance, study habits, and class participation, Random Forest can categorise students into groups such as "high-performing," "average," or "at-risk" in order to predict their performance. By offering feature importance scores and being resilient to noise and missing data, the algorithm assists teachers in determining the most significant elements influencing student performance. Random Forest is one of the most popular algorithms in educational data mining, despite being more computationally demanding than a single Decision Tree. It typically achieves higher accuracy and better generalisation (Breiman, 2001; Liaw & Wiener, 2002; Cortez & Silva, 2008).

Conclusion and Future Work

Machine learning-based student performance prediction has become an essential tool for enhancing learning outcomes and assisting academic institutions with data-driven decision-making. This survey highlights that a wide range of machine learning algorithms, including Decision Trees, Random Forests, Support Vector Machines, Logistic Regression, Naïve Bayes, and Neural Networks, have been successfully applied to predict student grades, identify at-risk students, and forecast dropout probabilities. Because they can handle non-linear relationships, minimise overfitting, and integrate multiple weak learners, ensemble-based techniques like Random Forest and Gradient Boosting consistently show higher predictive accuracy among these.

There are still issues in spite of the encouraging outcomes. A lot of research uses small, institution-specific datasets, which restricts how broadly the models can be applied. Furthermore, it is challenging to identify which interventions will most successfully enhance student outcomes because most research concentrates on predictive accuracy rather than causal inference. Future studies should investigate deep learning techniques on temporal datasets, hybrid models, and strategies that strike a balance between fairness, interpretability, and accuracy. Real-time prediction systems and extensive, cross-institutional research could improve machine learning's usefulness in education even more.

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