

Comparative Analysis of Different Student Performance Prediction Data-Mining Approaches

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ABSTRACT

Educational systems required innovative ways to enhance the quality of education so that optimal results with minimum failure rate can be obtained. This is because of the availability of large student dataset and hence the prediction of student performance becomes more challenging. This problem is resolved using data mining technique in the education field that helps to flourish the education system by predicting student performance and hence appropriate measures can be taken in advance. The system performance is affected by the incorrect attribute selection and the insufficient dataset, therefore, to overcome this problem, it is essential to conduct a deep study about the past work and hence select best and optimal prediction method. The main purpose of this article is to compare the various newly used data mining techniques, classification algorithms, and their impact on detection accuracy. The paper also identifies the best attributes to help the student performance prediction in an effective way.

Keywords: Education, data mining, student performance, Classification techniques, Accuracy.

INTRODUCTION

The performance of students is an integral part of higher education institutions. This is because the quality of the institute is based on their outstanding academic achievement record. According to previous literature, there are many definitions of student performance. In the year 2013, bin Mat et al. was pointed out that student performance can be obtained by measuring learning assessments and extra co-curriculum activities. However, some researchers have stated that graduation is a measure of a student's success [1].

Presently, there are a number of approaches that have been employed to evaluate students' performance. Among various available approaches, data mining is one of the most commonly used approaches for student performance analysis. The extraction of important information from large dataset is termed as data mining.

Data mining

Data mining techniques are utilized to process large amounts of data to find out hidden patterns as well as relations that contribute to decision making. Although, data mining and getting knowledge in databases are often treated as synonyms. The steps that are followed to extract data using data mining technique are shown in Figure 1.

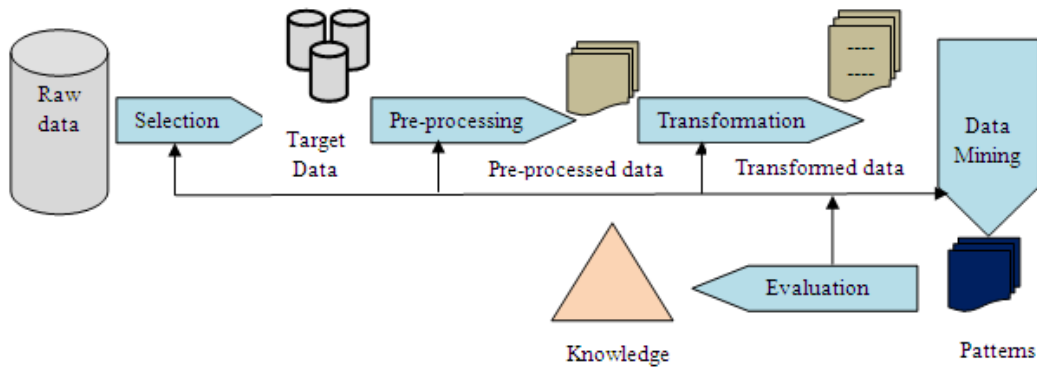


Figure 1: Data Mining Process [2]

- i. Data Collection: During the data collection process, it is essential to find and extract appropriate data for modelling. Initially, the availability of different data sources related to the work is determined as the data is available in various locations such as spreadsheet, files and in paper form.
- ii. Data integration: In this process, the collected data is combined i.e. the data, which is related to the same records, are put into one category. In this way, different categories of data are formed.
- iii. Data Selection: During this process, the selection of data that is useful for data mining has been performed i.e. only the important information is chosen.
- iv. Pre-processing: The main steps that are performed in data mining are the pre-processing that includes: cleaning, transformation and minimization of data size.
 - Data cleaning: It is used to remove irrelevant data so that the quality of data can be improved. It mainly comprises of fill in missing values and detects/ removes outliers.
 - Data Transformation: It is mainly utilized to convert the format of data that is the format of the source document as per the destination document format.
 - Data Minimization: For a large amount of dataset it is essential to decrease the size of the dataset before the data is passed to the data mining phase. It is supposed that the large data set can provide better results compared to small datasets. But, if the size of the data is removed that is the data that contains the irrelevant information then the size of the data can be reduced and it also helps to provide better results in less computation time.
- v. Building the model: During this step, a suitable data mining techniques such as clustering, association rule mining, pattern discovery and so on are selected to create a data mining model.
- vi. Interpretation: At this stage, the interpreter pattern is detected.
- vii. Decision: The output or the extracted knowledge is obtained at this stage [3-4].

Data mining is widely applied in the education field and is known as education data mining. During this process, the user data is extracted from the huge educational dataset. The extracted information can be utilized later to predict students' performance. In this way, it will assist the educators to offer an efficient teaching approach.

In addition, educators can also monitor student achievement. Students can improve their learning activities and also allow administrations to increase system performance. Therefore, the application of data mining technology can focus on the specific needs of different entities [5]. In order to meet these problems, an organized review is presented. The main objectives of this study, namely:

1. To examine the research gap in the past prediction education system.
2. To analyze the metrics used to verify the students' performance.
3. To review different approaches utilized for predicting student's performance.

The student performance prediction model has been proposed by (Soni et al; 2018) as shown in Figure 2. In this paper, the authors have created a student prediction model based on three different classification algorithms such as Decision tree (DT), naïve Bayes and Support Vector Machine (SVM). The student database consists of attributes such as family background and family income. From the results it has been analyzed that SVM technique performed well for predicting students' performance.

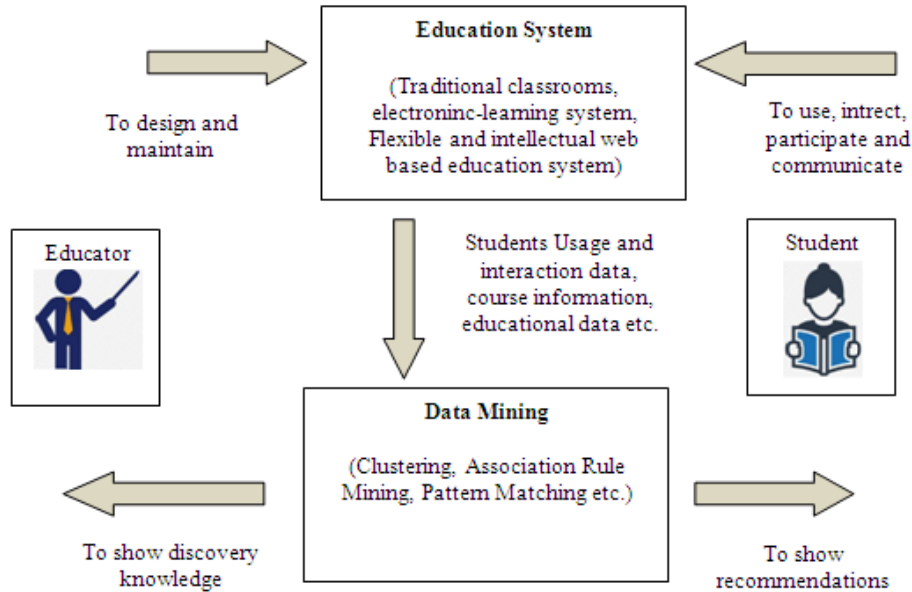


Figure 2: Data Mining Cycle for Educational Systems presented by (Soni et al; 2018) [6]

RESEARCH QUESTIONS

The research questions are essential or the foremost factors to understand the past work performed by various researchers in the prediction of student performance. According to (Shahiri et al; 2015), the research question criteria can be as depicted in Table 1.

Table 1: Research Question Criteria [7]

Research Criteria	Description
Population Size	Depends upon the university or student performance
Intervention	Techniques used for predicting performance
Outcomes	Examined in terms of accuracy, and the better prediction technique
Context	Educational institutes (All types)

Also, a list of traditional or the mostly used for the prediction of student performance is listed in Table 3.

Table 3: A list of Traditional Methods Proposed by Various Researchers

Attributes	Methods
Internal Assessments	<ul style="list-style-type: none"> DT Neural Network and K-nearest Neighbor
Internal Assessments and CGPA	<ul style="list-style-type: none"> SVM
Internal Assessments, Extracurricular activities and CGPA	<ul style="list-style-type: none"> Naïve Bayes K-nearest Neighbor SVM
CGPA, Student Demographics, High School Background, scholarship and social media interaction	<ul style="list-style-type: none"> Naïve Bayes Neural Network
External Assessment, Student	<ul style="list-style-type: none"> Neural Network

Demographics, High School Background	<ul style="list-style-type: none"> • Naïve Bayes
Student Demographics, High School Background	<ul style="list-style-type: none"> • Neural Network
CGPA, Student Demographics, High School Background, scholarship and, social media interaction, internal assessment, and Extracurricular activities	<ul style="list-style-type: none"> • DT
External Assessment, Student Demographic, CGPA and Extracurricular activities	<ul style="list-style-type: none"> • DT
Psychometric factors, Extracurricular activities and soft skill	<ul style="list-style-type: none"> • DT
CGPA	<ul style="list-style-type: none"> • Neural Network • Naïve Bayes
External Assessments	<ul style="list-style-type: none"> • DT
Psychometric factors	<ul style="list-style-type: none"> • DT • Neural Network • SVM and • K-nearest Neighbor

The essential attributes, as well as the related techniques used by the researchers in their past studied, is listed in Table 1. First one is the essential parameters on the basis of which a prediction model for determining the student performance is evaluated. The second one is the various methods that have been applied to predict the students' performance. Both of these are studies in detail in the following section.

Attributes used mostly for the student's performance prediction

According to the past studies it has been found that the student performance based on Cumulative Grade Point Average (CGPA) and internal assessment has been performed by (Quadri et al; 2010, Hämäläinen et al; 2006 and Angeline; 2013)[8-10].

The foremost idea to use these parameters to predict the performance of students is because these attributed have tangible values, which is beneficial for future education. Also, it can be considered as a point, which is essential for academic potential. Also, Christian and Ayub [11] were stated that CGPA is the most commonly used attributes for measuring the students' survival in their respective studies that is whether the students complete their study or not.

The researchers have designed a prediction model based on internal assessment that includes: assignment marks, lab work, class test, attendance and quizzes. Other researchers that have designed prediction model based on these parameters are: (Parack et al; 2012[12], Naren 2014 [13], Kumar et al; 2012 [14], Papamitsiouet al; 2014 [15]and Tucker et al; 2014)[16]. Second, the most commonly used attributes are student demographics (family background i.e. income, age, gender (male or female) & disability factor) and external assessments (marks obtained in the final exam). Most of the researchers have worked on student demographic factor this is because the learning style of girls and boys students is different. In 2007, the research, (Meit et al;) [17] have analyzed that the learning rate of girls is more positive compared to the boy's student.

They have also analyzed that the girls are more disciplined and obedient towards their studies and always focused on their studies. Also, authors Simsek and Balaban [18] have stated that the learning strategies of female students are more effective compared to male students.

The female students have a higher ability to effectively use self-motivated, organized and rehearsal performed by them. Therefore, it turns out that gender is one of the important attributes that affect student performance.

The other three parameters on the basis of which the student performance prediction model is designed are: extra-curricular activities presented by (Mayilvaganan et al; 2014 [19] and Naren 2014 [20]), high school background (Osmanbegovic et al. 2012 [21], Abu et al. 2012 [22] and Oladokun et al; 2008 [23]) and social interaction network (Romero et al; 2013 [24], Thai-Nghe et al; 2010 [25] and Yen et al; 2019 [26]).

There are also a number of researchers that have considered psychometric factor, a few of them are :

In 2014, Gray et al; [27] has investigated the psychometric parameter as an essential attribute to affect the academic performance using ANN and DT scheme. The researchers have worked on different factors such as personality, motivation as well as learning strategies. The detection accuracy of about 69 % and 65 % have been achieved using ANN and DT approach respectively.

Adejo et al. (2018) [28] have worked on psychological attributes to analyze the performance of student performance using SVM, ANN and DT technique. Also, the performance has been computed in terms of precision, recall, F-measure and classification error.

Prediction Methods Used For Student Performance Analysis

In educational data mining methods, predictive models are often used to predict student performance. To build a predictive model, several techniques were used, namely classification, regression and categorization. Among all, the most common task for predicting student performance is classification. In classification, also a number of methods have been used to predict student performance. A few of them are described in the subsequence section.

Neural Network

ANN is the most commonly used educational data mining technique used to predict the performance of student. The main advantage of this algorithm is that it is used to identify all possible interactions among predictor variables. The structure of ANN is shown in Figure 3.

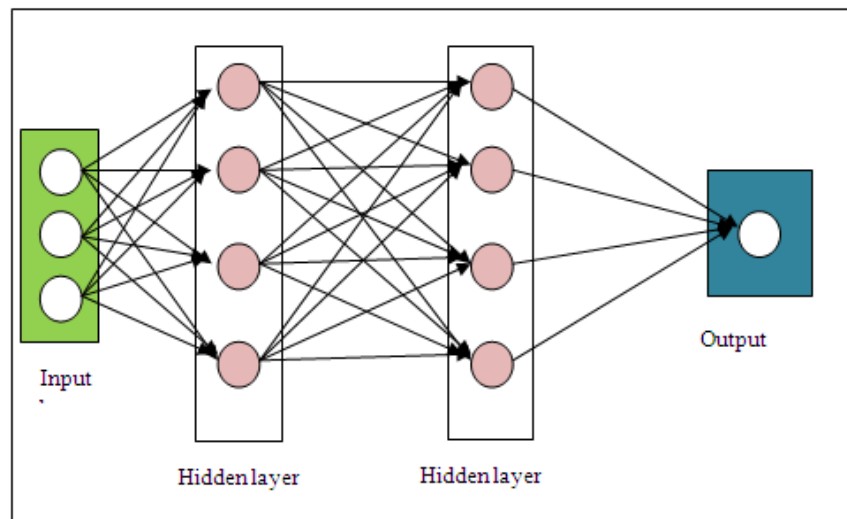


Figure 3: General ANN Structure

The researchers that have used the ANN technique to predict the student’s performance along with their detection accuracy is listed in table below.

Table 4: Detection Accuracy using ANN Approach

Authors	Technique Used	Criteria of grading	Detection Accuracy
Okuboet al. [29]		Attendance Quiz Report	>90 %
Chakraborty et al. [30]		Utilized to select quality students for Master of Business Administration (MBA) programs	91.667

	ANN	Gender SSC percentage HSC Percentage, Degree Percentage, SSC Percentage and Entrance test Percentile	
Gray et al [27]		psychometric parameter	69 %
Arsad et al. [31]		Exam Data	97
Oladokun et al. [23]		External assessment, Student Demographic, High school background	74%
Kumar et al. [14]		Internal assessments, External assessment	98%
Average			83.8

Decision Tree (DT) approach

Decision Tree Classification is a predictive modelling approach that uses a tree as a structure for representing. Decision Tree is often used to define the most optimal strategies for reaching a specific target for real-world settings because it can be easily transformed in steps. This feature explains their use of EDM when it's compatible with their fast training. The structure of DT is shown in Figure 4.

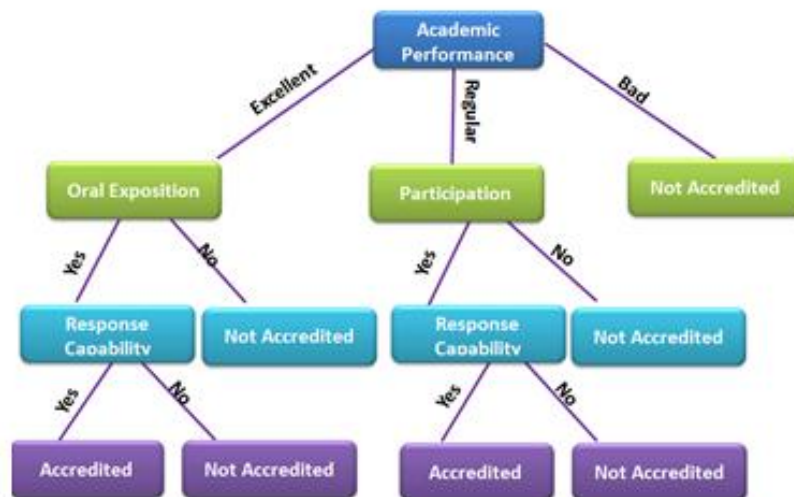


Figure 4: Decision Tree for classifying students as Accredited and Not Accredited [32]

In Figure 4, it has been illustrated that Accreditation and no- accreditation is categorized into two and five different ways respectively. Decision trees are a very good practical method because they are relatively fast and can be easily converted to simple classification rules. The decision tree method mainly depends on information gain indicator that determines the most useful attributes.

Table 5: Detection Accuracy using DT Approach

Authors	Technique Used	Criteria of grading	Detection Accuracy
Hamsa et al. [33]	DT	Internal, Sessional and Academic Score	70 %
Agaoglu [34]		course evaluation	92.5%
Gray et al. [27]		Psychometric Factor	65%
Bunkar et al. [35]		External assessment	85%
Zhoc et al. [36]		Psychometric factor	73%
Fernandes et al. [37]		Student Demographics	90 %
Average			79%

Bayesian Learning

This is a category of statistical classifiers, the working principle of which is based on Bayes' theorem that predicts class members by exploiting the probabilities of the diverse sets involved. The algorithm supposed that the outcomes of the attribute on the class are self-governing of the attribute. Also, one can say that each unit have different effect in the input vector and also independent of each other. Therefore, the joint conditional probability of various elements is represented in the form of graph in the input vector. Therefore, these are graphical models that can describe the joint conditional probabilities of different elements in the input vector. These are known for their high precision in certain areas, such as text analysis. This is mostly used in text analysis where high detection accuracy is required. Due to its advantages that it calculates the probabilities based on those outputs, the training is performed, which provides better results even with the noisy data. The probability can be calculated as;

$$P\left(\frac{f_k}{y}\right) = \frac{P(f_k p(y/f_k))}{p(y)}$$

$f_k \rightarrow$ The desired subjects to be predicted
 $Y \rightarrow$ Selected Semester

The following steps are followed to train the system using Naïve Bayes approach;

- i. Let T_{set} be a training set of students and the class labels, as well as every student, is represented by an nT_{set} attribute vector $Y=(sem1, sem2, sem3, \dots, semN)$.
- ii. Let us considered that there is n number of subjects represented by $S1, S2, S3, \dots, SM$.
- iii. The classification has to be performed to achieve the maximum posterior that is the maximal number of $P(S||Sem)$, which is obtained from Bayes theorem.

Table 6: Detection Accuracy using Naïve Bayes Approach

Authors	Technique Used	Criteria for grading	Detection Accuracy (%)
Ramesh et al. [38]	Bayesian Learning	Demographic of student and Background of High school.	50
Jishan et al. [39]		CGPA	75
Mayilvaganan et al. [19]		Internal assessment mark, CGPA, Extra - curricular activities	73
Mayilvaganan et al. [19]		Internal assessments, CGPA, Demographic of student.	73
Average			67.75

K Nearest Neighbor (KNN)

It a classification approach, which classified data based on the difference vectors from their nearest matching cluster. It is a kind of event-based learner that is termed as lazy learner. The categorization of already known data type is performed; therefore, it is the simplest and easiest method of KNN. The neighbouring point is calculated as per the K value, which also selects the class for the selected data type. Sometimes, it is used more than one nearest point to compute the class of data and hence known as KNN approach. This is a memory-based approach because; the data points must remain in their memory during the running process.

Table 7: Detection Accuracy using KNN Approach

Authors	Technique Used	Criteria for grading	Detection Accuracy
Amra et al. [40]	KNN and Naïve Bayes	Gender, background status and student status (passed or not)	Using KNN and Naïve Bayes, the detection accuracy of about 63.45 % and 93.17
Mayilvaganan et al. [19]	KNN	Internal assessment, CGPA, Extra-curricular activities	83%
Average			73 %

Support vector Machine (SVM)

This is a promising approach to classifying linear and nonlinear data. It utilized a non-linear mapping method to convert raw training data to higher dimension data. As, in student performance analysis, it consists of a number of attributes and hence termed as multidimensional objects. On the basis of this novel dimensional data, SVM search for the linear and best-separating hyperplane that is responsible to categorize data into various levels. This hyperplane can be decided by using support vector and edges. SVM is a robust and precise approach for pattern classification as well as to extract useful information and hence gain a little attention in the field of education mining.

Table 8: Detection Accuracy using SVM Approach

Authors	Technique Used	Criteria of grading	Detection Accuracy
Burman et al. [41]	SVM	Psychometric factors	89 %
Hämäläinen et al. [9]		Internal assessment, CGPA	80%
Mayilvaganan, et al. [19]		Internal assessment, CGPA, Extra-curricular activities	80%
Average			83 %

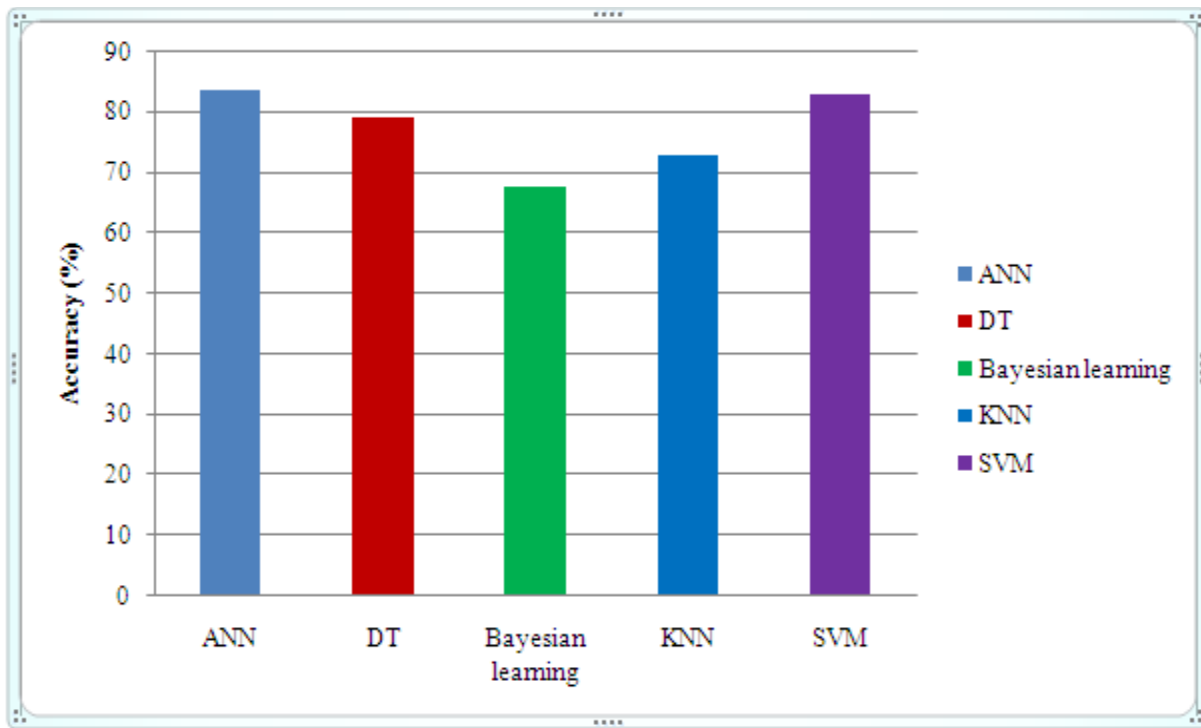


Figure 5: Comparison of Average Accuracy using a different approach

Figure 5 represents the comparison graph for the detection accuracy evaluated by the various researchers to analyze the student performance by considering different attributes. The graph represents that the highest accuracy has been obtained using the ANN approach followed by SVM approach.

This section demonstrates the result analysis of the past work performed by various researchers to predict student performance based on different attributes. The study has mainly focused on the detection accuracy with essential factors that affect student performance. The average detection accuracy determined by applying different classification approaches is shown in Figure 5. From the graph, it has been concluded that ANN has attained the highest detection accuracy about 83.8 % followed by SVM approach (83%). Next, the DT and KNN approach has achieved accuracy of 79% and 73 % respectively. At last, the lowest accuracy of 67.75 % has been obtained using Bayesian learning.

CONCLUSION

Predicting student performance is helpful for educators as well as students to enhance their learning and teaching capabilities. This study has reviewed past studies using various analytical approaches that are used to predict student performance. From the above study it has been observed that most researchers have considered CGPA and internal assessments as data sets. For predictive the performance, classification methods are often used in the field of educational data mining. Among different classification methods, ANN, DT and SVM are the most commonly used approaches for predicting the student performance. In future, the work can be performed using ANN or SVM approach for the prediction of student performance. As these techniques provide better accuracy compared to other existing classification approaches.

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