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Mining Educational Data to Predict Students' Future Performance using Naïve Bayesian Algorithm

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ABSTRACT

Higher education institutions want not only to provide quality education to its students but also to advice career options according to the prediction of students' performance. The students' satisfactory performance takes an important role to give birth the best quality graduates who will become competent laborers for the country's economic and social development [2]. Students' performance like who will pass and who are likely to fail can be predicted with the help of lots of features available. The students want to realize their final performance before the announcement of their results and before they attend their semester exams. According to their predicted performance, the students can improve their skills by proper planning to lead to a good performance in their end examination. To provide a good advice to such kind of student, educational data mining system is implemented to predict students' final performance evaluated by considering factors which include IM, PSM, Basics, ACIC, ASS, CP, ATT, ACOC and ESM. In this research, an attempt has been made to explore Naïve Bayesian classification to predict the students' future performance.

KEYWORDS: *Educational Data Mining, Naïve Bayesian Classification, Prior Probability*

1. INTRODUCTION

In higher learning institutions, students' performance is an essential part. This is because one of the criteria for a high quality university is depended on its excellent record of academic achievements [14].

At present, there are many techniques being proposed to evaluate students' performance. Data mining is one of the most popular techniques to evaluate students' performance. Data mining uses a combination of a vast knowledge base, advanced analytical skills, and domain knowledge to detect hidden trends and patterns which can be used in almost any sector ranging from business to medicine, then to Education. Nonetheless educational institutes can apply data mining to determine valuable information from their databases known as **Educational Data Mining (EDM)** [8]. It aims at devising and using algorithms to predict the student's future performance and improve educational results for further decision making [6].

Nowadays, where knowledge and quality are needed as critical factors in the global economy, Higher Education Institutes (HEI) as knowledge centers and human resource developers take part in a vital role. Thus, it is important to ensure the quality of the educational processes and to classify the performance of students [16]. The students' satisfactory performance takes an important role to give birth the best quality graduates who will become competent laborers for the country's economic and social development. Recruiting competent laborers especially the fresh graduates is one of the main aspects considered by the company [2]. Thus, students have to try with the greatest effort in their study to obtain a good performance in order to fulfill the company demand.

Data Mining task can be divided into two categories: Descriptive and Predictive. Descriptive mining tasks characterize properties of the data in a target data set. Predictive mining tasks execute induction on the current data in order to make predictions [10]. Predictive mining task is clustering, prediction and descriptive mining task is association rule and summarization.

Data mining techniques can contribute for future prediction about students' performance. The main goal of education system is to provide the quality education to students. Providing a high quality of education depends on predicting the unmotivated students before they entering in to final examination. For the improvement and development in education system, data mining can be very suitable [7]. Present paper is designed to mine the educational domain using Bayesian classification to predict the future performance of Engineering Students from LakiReddy Bali eddy College of Engineering, Dept of IT, Mylavaram from 2012 to 2016 [19].

There is no absolute scale for measuring knowledge but examination score is one scale which offers the performance indicator of students. Students' academic achievement is measured by the internal assessment and end semester examination. The internal assessment is carried out by the teacher based upon students' performance in educational activities such as the basic knowledge of the subject, ability to concentrate in the class, assignment, content perception, attendance and awareness on course.

Data mining provides many tasks that could be applied to study the students' performance. In this research, the classification task is used to evaluate student's performance of the final semester. Students' information like previous semester marks and educational activities marks were collected from the student's database system, to predict the performance at the end of the semester examination [19].

2. Related Work

Various data mining technique are used to analysis the academic performance of students at various levels, followings are the few of some especially used for academic progression in various modes.

Jayaprakash and Balamurugan [12] presented a system in which the naïve Bayes algorithm is applied to predict students' academic performance in end-of-semester examinations by analysing student feedback and their performance in mid-semester exams. This system provides educational institutions to identify the weaker students in advance and arrange necessary training before they sit for their final exams.

Ayesha, Mustafa, Sattar, M. Inayat Khan [23] used Bayesian Classification Method as a data mining technique and suggested that students' grade in senior secondary exam, living location, medium of teaching, mother's qualification, students' other habits, family annual income and students' family status were highly correlated with the student academic performance.

Al-Radaideh, Q., Al-Shawakfa, E. and Al-Najjar, M. [1] proposed the classification as data mining technique to evaluate students' performance. Decision tree method is applied for classification. This study supports earlier in identifying the dropouts and students who need special attention and allow the teacher to provide appropriate advising.

M. Wook, Y. Hani Yamaya, N. Wahab, M. Rizal Mohd Isa, N. Fatimah Awang and H. Yann Seong [15] compared two data mining techniques which are: Artificial Neural Network and the combination of clustering and decision tree classification techniques for predicting and classifying student's academic performance. As a result, the technique that provides accurate prediction and classification was selected as the best model. Using this model, the pattern that influences the student's academic performance was identified.

S. Kumar Yadav, B. Bharadwaj and S. Pal [22] collected the university student data such as attendance, class test, seminar and assignment marks from the students' database. They used three algorithms ID3, C4.5 and CART to predict the performance at the end of the semester and concluded that CART is the best algorithm for classification of data.

N. Thai Nghe, P. Janecek and P. Haddawy make a comparison of the accuracy of decision tree and Bayesian network algorithms for predicting the academic performance of under graduate and postgraduate students at two very different academic institutes. These predictions are most suitable for identifying and assisting failing students, and better determine scholarships. According to the result, the decision tree classifier provides better accuracy in comparison with the Bayesian network classifier [18].

Shaziya, Zaheer, and Kavitha [20] introduced an approach to predict the performance of students in per-semester exams by using naïve Bayes classifier. The main goal is to know the grades that students may obtain in their end-of-semester results. This approach helps the educational institution, teachers, and students, i.e., all the stakeholders take part in an educational system. They can profit from the prediction of students' results in a multitude of ways. Students and teachers can take required actions to improve the results of those students whose result prediction is not satisfactory.

Bharadwaj and Pal reviewed the university students data like attendance, class test, seminar and assignment marks from the students' previous database, to predict the performance at the end of the semester [5].

The proposed system used a training dataset of engineering students to build the Naïve Bayes model. Then, the model predicts the end-semester results of students by applying the test data. In this approach, a number of attributes is selected to predict the final grade of a student.

3. Data mining definition and techniques

Data mining also termed as Knowledge Discovery in Databases (KDD) refers to extracting or "mining" knowledge from large amount of data [13]. Fig.1 presents how to extract the well-defined pattern as a result of mining the data.

Fig. 1 – Conversion of data into a pattern

Knowledge Discovery process comprises various steps like Data cleaning, Transformation, Data mining, Pattern evaluation in extracting knowledge from data. Knowledge Discovery is associated with a multitude of tasks such as association, clustering, classification, prediction, etc. Classification and prediction are functions which are utilized to create models that are designed by analyzing data and then used for assessing other data. Classification techniques can be used on the educational data for predicting the students' behaviors, performance in examination etc. Basic techniques for classification are Decision Tree induction, Bayesian classification and neural networks. A number of well-known data mining classification algorithms such as ID3, REPTree, Simplecart, J48, NB Tree, BFTree, Decision Table, MLP, Bayesnet, etc., exist [11].

Schools and Universities apply Data mining as a powerful new technology with great potential to focus on the most important information in the data they have collected about the behavior of their students and potential learners [9]. Data mining associates with the use of data analysis tools to discover previously unknown, patterns and relationships in large data sets. These tools consist of statistical models, mathematical algorithms and machine learning methods.

These techniques are able to identify information within the data that queries and reports can't effectively reveal [6].

3.1 Data preparation

The data set applied in this study was collected from LakiReddy Bali reddy College of Engineering, Information Technology department, Mylavaram from session 2012 to 2016.

The experiment was carried out using the data set with 28 records using only 8 high impact attributes (Internal Marks (IM), Previous Semester Marks (PSM), Basic knowledge of the subject (Basics), Ability to concentrate in the class(ACIC), Assignment(ASS), Content Perception(CP), Tutorial(TUT), Attendance (ATT), Course Outcome Awareness (ACO)) and 9th attributes represents the unknown "End Semester Marks (ESM)" attribute that is to be predicted by the algorithm [19].

3.2 Data selection and transformation

In this step, only those fields were chosen which were required for data mining. The data values for some of the variables were defined for the present analyses which are described in Table 1 for reference.

Table1. Simple record of students' data set

Variable	Description	Possible Values
IM	Internal Marks	{A>=60% B>=45 & <60% C>=36 & <45% Fail<36%}
PSM	Previous Semester Marks	{Fail <36%, Average > = 36% and < 45%, Good > = 45% and<60%, Excellent >=60%}
Basics	Basics in the subject	{Weak, Average, Strong}
ACOC	Ability to Concentrate in the Class	{Weak, Average, Strong}
ASS	Assignment	{Yes – student completed assignment work assigned by teacher, No – student not completed assignment work assigned by teacher}
CP	Content Perception	{Weak, Average, Strong}
ATT	Attendance	{A,B,C}
Awareness on CO's	Course Outcomes Awareness	{Yes, No}
TUT	Tutorial	{Yes, No}
ESM	End Semester Marks	{Fail <36%, Average > = 36% and < 45%, Good > = 45% and<60%, Excellent >=60%}

3.3 Naïve Bayes Classifier Algorithm

Naïve Bayes is a statistical classifier that can be applied to predict the probability of membership in a class. Naïve Bayes theorem has similar classification capabilities to the decision tree and neural network. Naïve Bayes is validated to have high accuracy and speed when applied to databases with large amounts of data [3]. Naive Bayes is based on the simplifying assumption that attribute values are conditionally independent if given an output value. In other words, given the value of output, the probability of observing collectively is the product of the individual probabilities [3]. The advantage of using Naive Bayes is that this method requires only a small amount of training data to determine the estimated parameters required in the classification process. Naive Bayes often works much better in most complex real-world situations than expected. Bayes's theorem says:

$$P(H/X) = \frac{P(X/H)P(H)}{P(X)} \qquad (1)$$

where X is data of an unknown class, H is the hypothesis that X is from a specific class, $P(H/X)$ is the probability of hypothesis H based on condition X, $P(H)$ is the Probability hypothesis H(prior prob.), $P(X/H)$ is the probability of X under these conditions, and $P(X)$ is the probability of X [3].

The Bayesian classifier works as follows:

1. Let D be a training set of tuples and their class labels. Each tuple is represented by n-dimensional attributes vector, $X = (x_1, x_2, \dots, x_n)$, depicting n measurements made on the tuple from n attributes, respectively, $A_1, A_2, \dots, A_n$.
2. Suppose, there are m classes, $C_1, C_2, \dots, C_m$. Given a tuple, X, the classifier will predict that X belongs to the class having the highest posterior probability, conditioned on X belongs to the class C_i if and only if $P(C_i/X) > P(C_j/X)$ for $1 \ll j \ll m, j \neq i$. Thus we maximize $P(C_i/X)$.The class C_i for which $P(C_i/X)$ is maximized is called maximum posterior hypothesis.
3. As $P(X)$ is constant for all classes, only $P(X/C_i)P(C_i)$ need be maximized. If the class prior probabilities are not known, then it is commonly assumed that the classes are equally likely, that is, $P(C_1) = P(C_2) = \cdots. = P(C_m)$, and there will be maximization of $P(X/C_i)$. Otherwise, maximization will be $P(X/C_i)P(C_i)$.
4. Given data sets with many attributes, it would be extremely computationally expensive to compute $P(X/C_i)$. In order to reduce computation in evaluate $P(X/C_i)$, the Naïve assumption of class conditional independence is made. This presumes that the values of the attributes are conditionally independent of one another, given the class label of tuple. Thus,
$$P(X/C_i) = \prod_{k=1}^{n} P(X_k/C_i) \qquad (2)$$
5. In order to predict the class label of X, $P(X/C_i)P(C_i)$ is evaluated for each class C_i. The classifier predicts that the class label of tuple X is the class C_i if and only if $P(X/C_i)P(C_i) > P(X/C_j)P(C_j)$ for $1 \ll j \ll m, j \neq i$. In other words, they predict class label is the class C_i for which $P(X/C_i)P(C_i)$ is the maximum [21].

3.4 Experimental Results

In this paper, Naive Bayes classification algorithm can be applied to predict the class label of "End Semester Marks (ESM)" with the help of training data given in Table 2. There are 14 data sets belonging to the class "Average" and 14 data sets belonging to class "Fail". The data tuples are expressed by the attributes of Internal Marks (IM), Previous Semester Marks (PSM), Basic knowledge of the subject (Basics), Ability to concentrate in the class (ACIC), Assignment (ASS), Content Perception (CP), Attendance (ATT), Course Outcome Awareness (ACO) and Tutorial (TUT). The class label attribute "End Semester Marks (ESM)" has two distinct values namely {Average, Fail}. The prediction of any new student is shown in Table 3.

We need to maximize $P(X/C_i)$ for i=1,2, $P(C_i)$, the prior probability of each class, can be computed based on the training data set.

$$P(\mathrm{ESM} = Avg) = \frac{14}{28} = 0.5$$

$$P(\mathrm{ESM} = Fail) = \frac{14}{28} = 0.5$$

To compute $P(X/C_i)$ for i=1,2, $P(C_i)$, we compute the following probabilities:

$$P(\mathrm{ACO} = No/\mathrm{ESM} = Avg) = \frac{14}{14} = 1$$

$$P(\mathrm{ACO} = No/\mathrm{ESM} = Fail) = \frac{10}{14} = 0.714286$$

$$P(\mathrm{Baics} = Avg/\mathrm{ESM} = Avg) = \frac{12}{14} = 0.857143$$

$$P(\mathrm{Baics} = Avg/\mathrm{ESM} = Fail) = \frac{10}{14} = 0.714286$$

$$P(\mathrm{ACIC} = Strong/\mathrm{ESM} = Avg) = \frac{2}{14} = 0.142857$$

$$P(\mathrm{ACIC} = Strong/\mathrm{ESM} = Fail) = \frac{2}{14} = 0.142857$$

$$P(\mathrm{CP} = Avg/\mathrm{ESM} = Avg) = \frac{10}{14} = 0.714286$$

$$P(\mathrm{CP} = Avg/\mathrm{ESM} = Fail) = \frac{2}{14} = 0.142857$$

$$P(\mathrm{IM} = B/\mathrm{ESM} = Avg) = \frac{8}{14} = 0.571429$$

$$P(\mathrm{IM} = B/\mathrm{ESM} = Fail) = \frac{1}{14} = 0.071429$$

$$P(\mathrm{PSM} = Fail/\mathrm{ESM} = Avg) = \frac{6}{14} = 0.428571$$

$$P(\mathrm{PSM} = Fail/\mathrm{ESM} = Fail) = \frac{14}{14} = 1$$

$$P(\mathrm{ASS} = No/\mathrm{ESM} = Avg) = \frac{6}{14} = 0.428571$$

$$P(\mathrm{ASS} = No/\mathrm{ESM} = Fail) = \frac{14}{14} = 1$$

$$P(\mathrm{TUT} = No/\mathrm{ESM} = Avg) = \frac{6}{14} = 0.428571$$

$$P(\mathrm{TUT} = No/\mathrm{ESM} = Fail) = \frac{14}{14} = 1$$

$$P(\mathrm{ATT} = C/\mathrm{ESM} = Avg) = \frac{2}{14} = 0.142857$$

$$P(\mathrm{ATT} = C/\mathrm{ESM} = Fail) = \frac{10}{14} = 0.714286$$

Using above probabilities, we obtain
$P(New\ student/ESM = Avg) = P(ACO = No/ESM = Avg$ x $PBaics = Avg/ESM = Avg$ x $P(ACIC = Strong/ESM = Avg)$ x $P(CP = Avg/ESM = Avg$ x $PIM = B/ESM = Avg$ x $PPSM = Fail/ESM = Avg$ x $P(ASS = No/ESM = Avg)$ x $P(TUT = No/ESM = Avg)$ x $P(ATT = C/ESM = Avg)$
= 1 x 0.857143 x 0.142857 x 0.714286 x 0.571429 x 0.428571 x 0.428571 x 0.428571 x 0.142857
= 0.000562029

Similarly, we can find out
$P(\mathrm{New\ student/ESM} = Fail) = P(\mathrm{ACO} = No/\mathrm{ESM} = Fail)$ x $P(\mathrm{Baics} = Avg/\mathrm{ESM} = Fail)$ x $P(\mathrm{ACIC} = Strong/\mathrm{ESM} = Fail$ x $P\mathrm{CP} = Avg/\mathrm{ESM} = Fail$ x $P\mathrm{IM} = B/\mathrm{ESM} = Fail$ x $P(\mathrm{PSM} = Fail/\mathrm{ESM} = Fail)$x $P(\mathrm{ASS} = No/\mathrm{ESM} = Fail)$ x $P(\mathrm{TUT} = No/\mathrm{ESM} = Fail)$ x $P(\mathrm{ATT} = C/\mathrm{ESM} = Fail)$

= 0.714286 x 0.714286 x 0.142857 x 0.142857 x 0.071429 x 1 x 1 x 1 x 0.714286
= 0.000531244

To find the End Semester marks C_i that maximize $P(X/C_i)$ $P(C_i)$, we compute
$P(\mathrm{New\ student/End\ Semester\ marks} = Avg)$ x $P(\mathrm{End\ Semester\ marks} = Avg)$
= 0.000562029 x 0.5
= 0.000281015
$P(\mathrm{New\ student/End\ Semester\ marks} = Fail)$ x $P(\mathrm{End\ Semester\ marks} = Fail)$
= 0.000531244 x 0.5
= 0.000265622

Table2. Data Set for Engineering Student Data set

S. no.	ACO	Baics	ACIC	CP	IM	PSM	ASS	TUT	ATT	ESM
1	No	Avg	Avg	Avg	A	Avg	No	Yes	A	Avg
2	Yes	Avg	Avg	Strong	C	Fail	No	No	C	Fail
3	No	Avg	Avg	Weak	C	Fail	No	No	B	Fail
4	No	Avg	Strong	Strong	B	Fail	No	No	B	Avg
5	No	Avg	Avg	Avg	B	Fail	Yes	No	C	Avg
6	No	Avg	Weak	Avg	C	Fail	No	No	B	Fail
7	No	Avg	Avg	Avg	A	Avg	Yes	No	A	Avg
8	No	Avg	Avg	Strong	A	Avg	Yes	Yes	A	Avg
9	No	Avg	Strong	Strong	C	Fail	No	No	C	Fail
10	No	Weak	Weak	Weak	C	Fail	No	No	C	Fail
11	No	Weak	Weak	Avg	B	Fail	No	Yes	B	Avg
12	No	Weak	Weak	Weak	D	Fail	No	No	C	Fail
13	No	Avg	Avg	Avg	B	Avg	Yes	Yes	B	Avg
14	Yes	Avg	Avg	Strong	C	Fail	No	No	C	Fail
15	No	Avg	Avg	Avg	A	Avg	No	Yes	A	Avg
16	Yes	Avg	Avg	Strong	B	Fail	No	No	C	Fail
17	No	Avg	Avg	Weak	C	Fail	No	No	B	Fail

18	No	Avg	Strong	Strong	B	Fail	No	No	B	Avg
19	No	Avg	Avg	Avg	B	Fail	Yes	No	C	Avg
20	No	Avg	Weak	Avg	C	Fail	No	No	B	Fail
21	No	Avg	Avg	Avg	A	Avg	Yes	No	A	Avg
22	No	Avg	Avg	Strong	A	Avg	Yes	Yes	A	Avg
23	No	Avg	Strong	Strong	C	Fail	No	No	C	Fail
24	No	Weak	Weak	Weak	C	Fail	No	No	C	Fail
25	No	Weak	Weak	Avg	B	Fail	No	Yes	B	Avg
26	No	Weak	Weak	Weak	D	Fail	No	No	C	Fail
27	No	Avg	Avg	Avg	B	Avg	Yes	Yes	B	Avg
28	yes	Avg	Avg	Strong	C	Fail	No	No	C	Fail

Table3. Data set for a New Student

ACO	Baics	ACIC	CP	IM	PSM	ASS	TUT	ATT	FSM
No	Avg	Strong	Avg	B	Fail	No	No	C	?

In this way, the Bayesian classifier reliably predicts the new student will achieve the class "Average" in the End Semester. In the same manner another new students can be predicted to their respective performance based on the previous performance.

4. Conclusion

Data mining is a collection of algorithms that is employed by office, governments, university and corporations to predict and establish trends with specific purposes in mind. In this paper, Bayes algorithm is applied to explore the possibility of predicting student' final performance based on the information like Internal Marks (IM), Previous Semester Marks (PSM), Basic knowledge of the subject (Basics), Ability to concentrate in the class (ACIC), Assignment (ASS), Content Perception (CP), Attendance (ATT), Course Outcome Awareness (ACO) and Tutorial (TUT). This proposed system will help to the students and the teachers to enhance the students' final performance in the future assessment. This study will also work to identify those students which needed to try best to improve their performance to pass the examination and to get the good career.

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