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Using Data Mining Techniques to Predict Student Performance to Support Decision Making in University Admission Systems

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ABSTRACT An admissions system based on valid and reliable admissions criteria is very important to select candidates likely to perform well academically at institutions of higher education. This study focuses on ways to support universities in admissions decision making using data mining techniques to predict applicants' academic performance at university. A data set of 2,039 students enrolled in a Computer Science and Information College of a Saudi public university from 2016 to 2019 was used to validate the proposed methodology. The results demonstrate that applicants' early university performance can be predicted before admission based on certain pre-admission criteria (high school grade average, Scholastic Achievement Admission Test score, and General Aptitude Test score). The results also show that Scholastic Achievement Admission Test score is the pre-admission criterion that most accurately predicts future student performance. Therefore, this score should be assigned more weight in admissions systems. We also found that the Artificial Neural Network technique has an accuracy rate above 79%, making it superior to other classification techniques considered (Decision Trees, Support Vector Machines, and Naïve Bayes).

INDEX TERMS Data mining techniques, educational data mining, performance prediction, pre-admission criteria, student performance.

I. INTRODUCTION

Today, all higher education institutions, especially computer and engineering colleges, face challenges in the admissions process. Each university should strive for an admissions system based on valid and reliable admissions criteria that select candidates likely to succeed in its programs. In addition, each university should use the best possible techniques for predicting applicants' future academic performance before admitting them. This would support university decision makers as they set efficient admissions criteria.

However, most higher education institutions face challenges when they analyze their large educational databases to predict students' performance [1]. This is because they use only conventional statistical methods rather than new and efficient predictive techniques such as Educational Data Mining (EDM), which is the most popular technique to evaluate and predict students' performance [2]–[6]. EDM is the process of extracting useful information and patterns from a huge educational database [2], which can then be used to predict students' performance. As a result of better information, student performance can be more effectively improved through more effective strategic programs.

In this context, this study focuses on supporting universities in making admissions decisions through the application of data mining techniques to better predict applicants' academic performance before admission.

More specifically, this study addresses the following questions:

1) Is it possible to identify the admission criterion that most accurately predicts applicants' future academic performance?
2) Is it possible to predict applicants' early academic performance before admitting them based on their pre-admission test scores?

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3) Which data mining prediction technique among Artificial Neural Network (ANN), Decision Trees (DT), Support Vector Machines (SVM), and Naïve Bayes performs best in this study?
4) Do students' first-year academic performances improve when more weight is assigned to the most significant admission criterion?

This study contributes to the literature in several ways. First, we develop and test four predictive models using data mining classification techniques to predict early academic performance among applicants based on their pre-admission profiles. The information in these profiles most often used to predict student performance in higher education includes quiz scores, final exam scores, participation in extra activities, student demography, overall grades, and social network interactions (e.g. [7]–[10]). However, variables such as pre-admission test scores are rarely considered in the admissions process (e.g. [11]–[13]) to predict future student performance. These underused metrics are the focus of this study. In addition, we identify the best of four classification techniques to predict student performance in terms of accuracy, precision, recall, and $F1$-Measure metrics.

Second, through a correlation coefficient analysis, we determine the relation between admissions criteria and students' Cumulative Grade Point Average (CGPA) during their first year of study at university. We also identify admission criterion that most accurately predicts student performance so that decision makers can assign more weight to this particular criterion.

Third, based on the results and recommendations provided by this study, the university where this study was conducted decided to change the weighting of its admission criteria. This study proved the efficacy of such a decision by comparing the first-year CGPAs of new students admitted using the new system to the first-year CGPAs of students admitted using the old system. The percentage of students who achieved excellent or very good first-year CGPAs increased by 31%, and the percentage of the students who got acceptable or poor first-year CGPAs decreased by 18%.

Finally, this study differs from other studies in the field of predicting student performance because it had a large sample size of 2,039 students of the College of Computer and Information Sciences (CCIS) at Princess Nourah bint Abdulrahman University (PNU), located in Riyadh, Kingdom of Saudi Arabia (KSA). It is the largest university for women in the world. Most of the work that has been done in this field uses much smaller sample sizes in their model performance validation.

In our extensive search of research literature in KSA, we found only one published study [14] in the field of admissions criteria analysis the role admissions criteria play in predicting student performance in the computer science and technology colleges of Saudi public universities. That study addressed the relationship between pre-university exams and student performance at university. However, it applied only one statistical model (regression) that was not compared to other significant DM techniques. Also, the study used data from only one department (the Information Technology department) of the Computer College. In addition, the study's recommendations were not applied at the university where the study was conducted, and so the study's recommendations were never tested.

To the best of our knowledge, the few other related studies on this topic in KSA were focused exclusively on medical school students (e.g. [11]–[13], [15]–[17]). In addition, these studies used statistical software for data analysis rather than EDM techniques.

In 2016, two studies [18] used EDM to predict the students GPA based on their performance in previous courses, but they have not addressed the relationship between the student performance and university admission criteria.

We further detail the related work and research gap in Section 2.

The rest of this paper is organized as follows. Section 2 details the related work and research gap. Section 3 describes the domain of the study. Section 4 explains its methodology. Section 5 presents the experimental evaluation. Section 6 outlines our conclusion, recommendations, and some potential future work.

II. RELATED WORK AND RESEARCH GAP

In higher learning institutions, student performance is the factor most important to a university's quality. EDM is currently the technique most commonly used by researchers to evaluate and predict student performance due to its significance in decision making [3]–[7].

Predicting student performance has two main factors: attributes and prediction methods [19]. It has been shown in [19] that student CGPA is the most frequently used attribute in predicting student performance at university. It has been used in many researches (e.g. [7]–[10], [20]). Other attributes commonly used by researches to predict student performance at university are: assessments, quiz grades, lab work, and final exam grades (e.g. [8], [9], [21]). Few researches have used other attributes like extra activities, student demography, and social interaction network (e.g. [19], [22]).

However, input variables such as pre-admission tests are rarely used (e.g. [11]–[13]) to predict student performance at university in the admissions process. This is the focus of this study.

Several data mining classification techniques have been applied for prediction of student performance. For example, ANN is used in study [21] to predict the academic performance of 505 students in their eighth semester. Regarding Decision Trees, study [9] proposed a model to predict student performance in certain courses using small student sample sizes (32 and 42 students). Naïve Bayes is applied in study [23] on a set of 1,600 students to predict performance in a particular course. SVM is applied by study [24] on a data set of 1,074 students to predict students at risk performance in their first year of study.

The analysis of the literature reveals that most available studies do not explore the relationship between students' pre-admission exam scores and their expected academic performance at university in the admissions process. Thus, this study fills a research gap.

In this study, different admissions criteria were used as input attributes to predict students' first-year CGPAs in the computer sciences colleges of Saudi public universities.

Most of the few published related studies performed in KSA have been confined to medical colleges (e.g. [11]–[13], [15]–[17]). These studies have not used EDM, which can discover hidden patterns in institutions' large datasets, and therefore enhance their decision making. One of the very few studies related to this topic that has been confined to a computer science college is study [18], which applied one of the EDM techniques (i.e., J48 decision tree) to predict students' final GPA based on their grades in all courses. The authors of [18] collected data from the academic transcripts of 236 students of the Computer Science College at King Saud University (KSU) in KSA. They identified which courses in the study plan most strongly affect final GPA. However, they applied only one EDM technique on a very small dataset to predict student performance and did not ensure the accuracy of their results by using additional EDM techniques.

Another study that related to this topic in KSA is study [25], which applied three EDM techniques (Naïve Bayes, ANN, and Decision Tree) to predict student performance based on their academic records and forum participation. By comparing results of the three prediction techniques, they found that Naïve Bayes outperformed others by achieving a prediction accuracy rate of 86%.

However, the studies [18], [25] have not assessed the relationship between admission criteria and computer science student performance in Saudi public universities, which is the focus of this study.

To the best of our knowledge, the only related published study that addressed this topic is study [14]. In this study, the authors applied regression techniques on a dataset of 657 students to determine whether pre-admission exams have a significant effect on student GPA. They found that high school final grade affects college GPA more than pre-admission exam scores. These findings differ from the findings of this study.

However, their data was collected from only one department (the Information Technology department) of the Computer Science College at KSU, which has five departments. In addition, they only used one statistical process (i.e., Regression Analysis) rather than applying different EDM models to predict student performance, which could have enhanced their findings.

III. UNDERSTANDING THE DOMAIN OF THE STUDY

In KSA, enrollment in the computer science and technology colleges of public universities has increased from 2,959 students in academic year 2004-2005 to 27,089 students in academic year 2016-2017 [26]. Since the early 2000s, all Saudi public universities have central policies and procedures for student admissions that are controlled by the Saudi Ministry of Education [27]. Before an applicant can be admitted into any undergraduate program at any Saudi public university computer science and technology college, he/she is expected to take two standardized tests administrated by the National Assessment Center for Higher Education. These tests are the General Aptitude Test (GAT) and the Scholastic Achievement Admission Test (SAAT). While the GAT assesses mathematical and verbal skills to measure students' comprehension, logical reasoning, problem solving, and inductive/deductive skills, the SAAT assesses comprehension, application, and inference in five subjects: biology, chemistry, physics, mathematics, and English [28].

Admissions is based primarily on the weighted average score of three criteria: the High School Grade Average (HSGA), the SAAT, and the GAT. Each public university assigns certain weights to these three criteria, and each program identifies a cut-off point for weighted averages based on the number of available seats in each year. For example, in academic year 2017-2018, the weights of these three criteria in the four most famous Saudi public universities are, for the three criteria (HSGA, SAAT, and GAT), respectively: 30%, 40%, and 30% at KSU [29]; 50%, 20%, and 30% at King Abdulaziz University [30]; 20%, 50%, and 30% at King Fahd University of Petroleum & Minerals [31]; and 60%, 20%, and 20% at PNU [32].

However, it is difficult to determine appropriate weights for these criteria because of the lack of existing studies in KSA to analyze the relationship between these criteria and the student performance at university. This study will help in selecting students through a more appropriate system of weights that prioritizes the correct criteria.

IV. METHODOLOGY

1) To answer the first question in this study (Is it possible to identify the admission criterion that most accurately predicts applicants' future academic performance?), we developed a model using the Linear Regression technique, which is widely used for finding relationship between independent variables (i.e., predictors) and a dependent variable (i.e., response). The model helped us to determine the relationship between the three admission criteria (HSGA, SAAT, and GAT) as the independent variables, and the CGPA through students' first two semesters as the dependent variable. To describe the strength the linear relationship between each admission criteria and the CGPA, we used the correlation coefficient, which are usually used in statistics to measure the strength and direction of the linear relationships between two variables. In addition, to describe the percentage of the effect of each admission criteria on the students' first-year CGPA, we used the coefficient of determination.

2) To answer the second question in this study (Is it possible to predict applicants' early academic performance before admitting them based on their pre-admission test scores?),

we developed four prediction models by applying four well-known data mining classification techniques, namely: Artificial Neural Network (ANN), Decision Tree, Support Vector Machine (SVM), and Naive Bayes.

There are multiple DM classification techniques, however, our choices in this paper are these four well-known ones because of their critical features, which we briefly describe in the next paragraphs:

A. ARTIFICIAL NEURAL NETWORK (ANN)

ANN is a popular technique in EDM, and is designed to mimic the structure of the human brain to solve complex problems. It consists of a set of units that accept a weighted set of inputs and responds with an output.

Many published papers have used ANN to predict students' performance (e.g., [8], [21], [23], [24], [33]). We, also, used it because of its ability to detect all possible interactions among variables and its ability to learn from a limited set of examples. In addition, ANN models were found in a previous study to outperform classification techniques in correctly classifying admitted applicant who will accepted and not accepted [33]. In this study, we used the Multilayer Perception (MLP) topology for the ANN model due to the nature of the datasets, which were not large enough to require more complex topologies.

B. DECISION TREE

Decision Tree is based on a set of nodes that are arranged from the top to the bottom of the tree. Each node represents a feature of an instance, and its branches represent possible values. We used this technique because it is widely used by researchers due to its simplicity (e.g., [1], [6], [7], [9], [34]). It predicts values in a simple and straightforward way. In addition, it has some advantages like represents rules that could be understood and interpreted easily by users, perform well for categorical and numerical attributes, and does not require complex data preparation [6].

C. SUPPORT VECTOR MACHINE (SVM)

This classification technique builds a hyperplane that separates objects based on their classes. The larger the distance from the hyperplane to the nearest object becomes, the lower the generalization error of the SVM technique becomes. SVM is used in few researches (e.g., [7], [23], [24]) and is used in this study because it is well suited for small datasets. Further, it is faster than the other techniques [19].

D. NAIVE BAYES

Naive Bayes is a simple probabilistic technique based on applying Bayes' theorem with independent assumptions between variables. It assigns probabilities to each object for each possible class. In this study, we chose to use this technique due to its simplicity, very good performance for real-world problems, computational efficiency [35], and popularity in the related research literature (e.g., [7], [23], [24], [35]–[37]).

3) To answer the third question in this paper (Which data mining prediction technique performs best in this study?), we evaluated and compared the performance of the four models by using accuracy, recall, precision, and $F1$-Measure metrics. (See Evaluation Metrics in Subsection A, Experimental Setup at the following section)

4) To answer the fourth question in this study (Do students admitted under the new weighting system achieve better academic performance during their first two semesters than past students admitted under the old weighting system?), we developed the second stage of the study to compare the first-year CGPAs of new students admitted for academic year 2018-2019 under the new admission criteria weights to the first-year CGPAs of past students admitted for academic years 2016-2017 and 2017-2018 under the old admission criteria weights.

V. EXPERIMENTAL EVALUATION

A. EXPERIMENTAL SETUP

1) DATASET

This study was conducted with the records of students enrolled in the CCIS at PNU. The methods used, however, are general and can be used in any higher education institution. The data was obtained from the academic electronic database of the office of the Admitted and Registration Deanship. The required ethical approval was obtained from the Institution Review Board of PNU (Number 19-0152). PNU is the only public female-only university in KSA and is also the largest university for women in the world. The campus is 32 million square feet and has approximately 50,000 students and more than 5,000 academic and administrative staff. The CCIS was established in 2007 to fulfill the growing need in KSA for female higher education in the fields of computer science and technology. CCIS has three departments: Computer Science, Information Systems, and Information Technology. The programs of the three departments in CCIS are completed during students' four-year study plans. Each year is divided into two semesters.

In the first stage of this study, we collected a total of 1,569 student records from all three departments from two batches, namely 902 students from academic year 2016-2017 and 667 students from academic year 2017-2018. All students of this study were Saudi females, who live in the same region (the central region of the Kingdom of Saudi Arabia). In addition, all students do not work while in college, but they all receive a monthly salary from the government. The acceptance of the students from both batches was based primarily on three admission criteria: HSGA, SAAT, and GAT, for which the assigned weights were 60%, 20%, and 20%, respectively.

Based on the results and recommendations provided by the first stage of this study, which shows that SAAT score is the admission criterion that most accurately predicts student performance, PNU decided to change the weighting of its admission criteria. The weights were changed to the

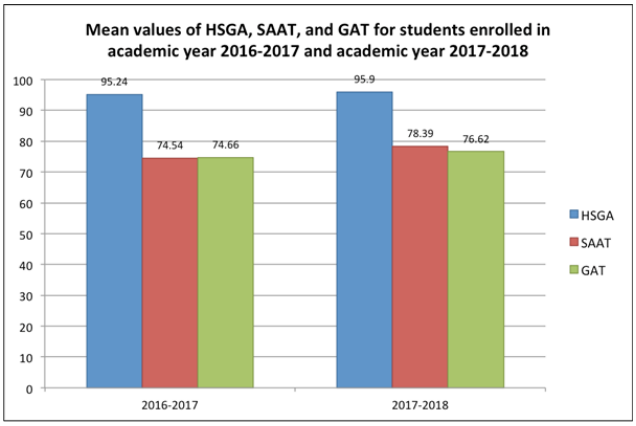

FIGURE 1. Mean values of HSGA, SAAT, and GAT for students enrolled in academic year 2016-2017 and academic year 2017-2018.

following for HSGA, SAAT, and GAT, respectively: 30%, 40%, and 30%.

In the second stage of this study, we collected a total of 470 student records from all three departments from academic year 2018-2019, for which student acceptance was based on the new assigned weights. Other students' conditions were similar to those mentioned in the first stage of the study. We used this data set to compare the first-year CGPAs of new students to the first-year CGPAs of students admitted under the old admission criteria weights.

All collected data sets were organized in Microsoft Excel, and each student's record included scores on the three admission criteria (all values between 0 and 100), and her CGPA after her first two semesters (all values between 0 and 5) Data is then converted from the Excel file into the standard format required by the Waikato Environment for Knowledge Analysis (WEKA) tool [38], which we used in this study for the Data Mining techniques. WEKA is an open source tool coded in Java, and we selected it because it is widely used in EDM research.

For the first stage of the study and before applying the EDM techniques, we prepared the data set with pre-processing. We took steps such as eliminating certain irrelevant attributes (e.g., student ID, name, and address), identifying outliers, deleting records with missing values, and removing duplicates. The total remaining number of student records after the previous data pre-processing was 1,430 records for 828 students from academic year 2016-2017 and 602 students from academic year 2017-2018. Fig. 1 shows mean values for HSGA, SAAT, and GAT.

We constructed a categorical target variable (class) based on the original numeric parameter CGPA. It has five categories according to the five-level scale that is used in PNU grade system, which based on the following ranges: excellent ($\geq$4.5), very good (3.75 to $<$ 4.5), good (2.75 to $<$ 3.75), average (2.0 to $<$ 2.75), and poor ($<$2.0). The CGPA distribution for students enrolled in academic year 2016-2017 and academic year 2017-2018 is shown in Fig. 2.

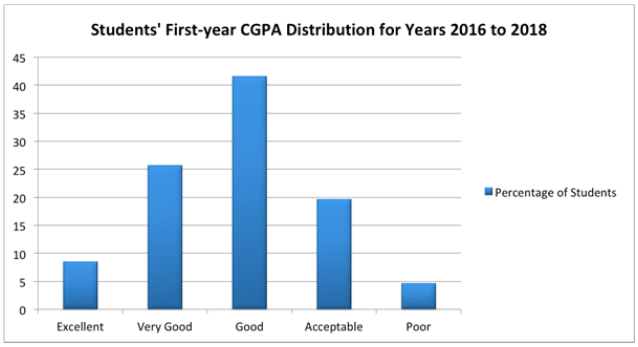

FIGURE 2. Students' first-year CGPA distribution for academic year 2016-2107 and academic year 2017-2018.

We also applied pre-processing to the data set of academic year 2018-2019 through some data pre-processing as we did to the data sets for academic years 2016 to 2018. The total number of remaining student records for academic year 2018-2019 was 437.

We developed four prediction models by applying four well-known data mining classification techniques, namely: Artificial Neural Network (ANN), Decision Tree, Support Vector Machine (SVM), and Naive Bayes. Each model was built using 10-fold cross validation, in which 9 sets of data were used for training the model and the remaining set was used for testing purposes. The process was repeated 10 times, ones for each of the different sets. This process maximized the total number of observation used for testing. All models were run using the parameter values defined by default in WEKA software.

2) EVALUATION METRICS

The performance of the data mining models can be determined by using the following concepts:

- True Positive Rate (TP): the number of instances that are correctly predicted as positive.
- False Positive Rate (FP): the number of instances that are incorrectly predicted as positive.
- True Negative Rate (TN): the number of instances that are correctly predicted as negative.
- False Negative Rate (FN): the number of instances that are incorrectly predicted as negative.

Accuracy is the percentage of correctly predicted results and is measured with (1):

$$Accuracy = (TP + TN)/(TP + TN + FP + FN) \quad (1)$$

Recall is the percentage of positives that are correctly predicted as positive and is measured with (2):

$$Recall = TP/(TP + FN) \quad (2)$$

Precision is the percentage of correct positive observations and is measured with (3):

$$Precision = TP/(TP + FP) \quad (3)$$

TABLE 1. The correlation coefficient between admission criteria and CGPA.

Independent Variables	CGPA
HSGA	0.20913
SAAT	0.44134
GAT	0.33783

TABLE 2. The coefficient of determination between admission criteria and CGPA.

Independent Variables	CGPA
HSGA	0.03523
SAAT	0.19257
GAT	0.13865

$F1$-Measure conveys the balance between the recall and the precision, and it emphasizes the performance of a classifier on common and rare categories, respectively [34]. It is measured with (4):

$$F1Measure = 2 \times Recall \times Precision/(Recall + Precision) \quad (4)$$

B. EXPERIMENTAL RESULTS AND DISCUSSION

1) MOST SIGNIFICANT CRITERION IDENTIFICATION

The results of this study showed that students' first-year CGPAs could be predicted based on admission criteria, which underscores their importance as significant predictors of student performance in Saudi higher education institutions. To identify the admission criterion that most accurately predicts student academic performance at university, we used the result of the correlation coefficient between the variables, as demonstrated in Table 1, and the coefficient of determination between the variables, as demonstrated in Table 2.

Analysis of Table 1 shows that SAAT scores have the strongest correlation with first-year CGPAs at the value of 44% of all other independent variables.

In addition, the percent impact of SAAT score on student first-year CGPA is 19%, which is the highest percent impact among the admission variables, as shown in Table 2.

Therefore, SAAT score is the admission criterion that most accurately predicts later academic performance at university. More weight should therefore be assigned to it. This result matches those of other national studies conducted in KSA (e.g., [11], [12], [15], [16]), which also show that SAAT score is the most significant positive predictor of student performance in Saudi medical schools. However, our result contradicts what is proposed in another national study [14], which found that the HSGA affects student CGPA more than the other two criteria. This difference could be attributed to many factors, such as the fact that HSGA score represents attainment in all high school subjects including those that are not related to computer science. In addition, the high school subjects are taught in Arabic language, while the computer college courses are conducted in English.

TABLE 3. Prediction techniques performance.

Classification Techniques	Accuracy	Recall	Precision	$F1$-Measure
ANN	79.22	78.03	81.44	79.70
Decision Tree	75.91	80.24	81.02	80.63
SVM	75.28	75.58	75.30	75.44
Naive Bayes	73.61	73.38	73.54	73.46

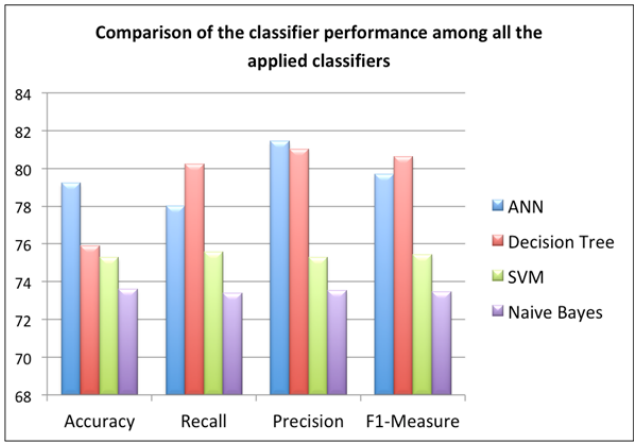

FIGURE 3. Comparison of the classifier performance among all the applied classifiers.

2) CLASSIFICATION TECHNIQUE PERFORMANCE

After implementing the four mentioned classifying techniques, their performance is shown in Table 3.

Comparison of the classifier performance among all the applied classifiers is demonstrated in Fig. 3.

Analysis of Table 3 shows that it is possible to predict applicants' early academic performance at university before admitting them based on their admission criteria. Accuracy, recall, precision, and $F1$-Measure are high when applying each classifier technique. Therefore, the institution in charge may adopt these techniques to predict students' academic performance before accepting them.

As shown in Fig. 3, the ANN classifier technique outperforms the other techniques in both explored performance metrics: the accuracy rate (79%), which represents classifier effectiveness, and the precision rate (81%), which represents classifier predictive power. This result corroborates the result in other studies [8, 24]. In addition, the DT classifier technique outperforms the others in the recall rate (80%), which represents classifier sensitivity, and in the $F1$-Measure rate (81%), which conveys the balance between the recall and the precision. This result matches the results of other studies (e.g., [7], [35], [39]).

Further, the SVM classifier technique shows accurate predictions. As in other studies (e.g., [36], [37]), the NB classifier technique performs worse than the other techniques,

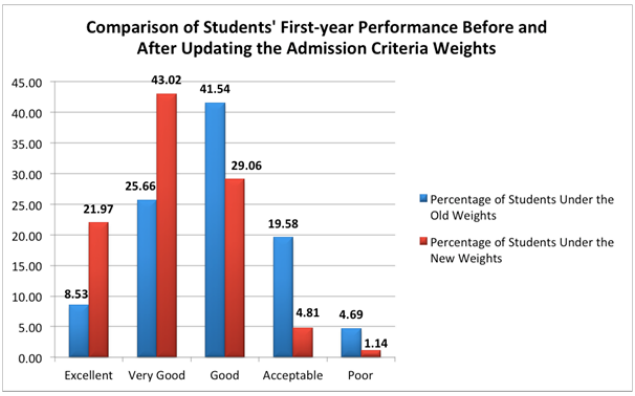

FIGURE 4. Comparison of students' first-year performance before and after updating admission criteria weights.

showing the lowest values of all the four considered performance metrics.

According to these results, we may conclude that, in this particular setting, the ANN classifier technique generally outperforms the other techniques. The superiority of the ANN technique in predicting student performance has been widely discussed in the literature (e.g., [19], [24], [40]).

3) STUDENT PERFORMANCE IMPROVEMENT

Based on the results and recommendations provided by this study, the PNU Admitted and Registration Deanship decided that the current admissions system should be changed to modify the weights of admission criteria to ensure high performance of first-year students. The deanship decided to add more weight to the SAAT criterion and change the weights of the three admission criteria (HSGA, SAAT, and GAT) to be 30%, 40%, and 30%, respectively, for academic year 2018-2019. The previous corresponding weights were 60%, 20%, 20%, respectively.

Fig. 4 shows the comparisons between the new students' first-year CGPAs to first-year CGPAs for students from previous years.

As shown in Fig. 4, after adding more weight to the most significant admission criterion (SAAT score), the percentage of students who achieved an excellent or very good first-year academic performance increased from 34% in academic year 2016-2018 to 65% in academic year 2018-2019. In addition, the percentage of the students who achieved an acceptable or poor first-year academic performance decreased from 24% in academic year 2016-2018 to 6% in academic year 2018-2019. This result corroborates the recommendation of this study to assign more weight to the admission criterion that most accurately predicts future student performance.

VI. CONCLUSION

The aim of this study is to support higher education institutions in making good decisions in its admissions process by predicting applicants' academic performance before admitting them. Four prediction models were proposed and developed using four well-known data mining techniques, namely: Artificial Neural Network (ANN), Decision Tree, Support Vector Machine (SVM), and Naive Bayes. The study was conducted with a dataset of 2,039 records of students enrolled in PNU, one of the largest universities in KSA. The methods used, however, are general and can be used in any higher education institution.

The study confirms the effectiveness of prediction modeling in higher education institutions where decision makers can use these models in planning and optimizing institutions' limited resource allocations.

In addition, the results show that a high performance model to predict students' early performance could be developed based on pre-admission information. For example, in this particular study, the ANN model was able to reach performance accuracy levels of about 79.22%.

Moreover, the results of this study show that ANN technique outperforms the others in both accuracy and precision metrics, while the Decision Tree technique outperforms the others in recall and $F1$-Measure. The Naive Bayes had the worst results.

This study concludes that SAAT score is the admission criterion that most accurately predicts later academic performance and that more weight should therefore be assigned to it. Based on this recommendation, decision makers at PNU, where this study was conducted, reviewed the admissions system and decided to modify the weights of their three admission criteria mentioned in this study by assigning more weight to SAAT score.

To investigate how the new admission process impacts student performance at PNU, this study compares the first-year CGPAs of students admitted using the old admissions weighting system to the first-year CGPAs of students admitted under the old weighting system. The results show that, after applying the new admission weighting system, the percentage of students who achieved excellent or very good first-year CGPAs increased by 31%, and the percentage of the students who achieved acceptable or poor first-year CGPAs decreased by 18%.

A. RECOMMENDATIONS

- Decision makers in Saudi computer science colleges should give serious consideration to students' pre-admission SAAT scores before accepting them.
- Other important pre-admission exams, which measure English-language proficiency should be added to the admission process for engineering and computer science colleges, because all courses in these colleges are conducted in English.
- Higher education institutions should consider more pre-admission variables that may affect future student performance such as parent education, previous high school (national or international), social interaction network, and programming knowledge.
- By applying data mining techniques, institutions can identify students in risk situations very early, which

will help decision makers to give them more attention and to build a strategic plan to improve their academic performance.

B. FUTURE STUDY

All classification techniques were applied on data collected from a single university in Saudi Arabia. Thus, to validate these findings further, more studies should use data from multiple Saudi universities, as well as American and European universities. In addition, further studies are needed to consider more pre-admission factors that affect future student performance, such as student personality, student demography, student family, and communication skills. For future study, other data mining techniques such as clustering may be used.

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