International Journal of Computer Trends and Technology
ISSN: 2231 – 2803 / https://doi.org/10.14445/22312803/IJCTT-V70I10P103

Volume 70 Issue 10, 13-21, October 2022

Original Article

Prediction and Classification Model for Academic Performance in Higher Institutions using Fuzzy Logic

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Received: 30 August 2022 Revised: 04 October 2022 Accepted: 16 October 2022 Published: 28 October 2022

Abstract - *Predicting student academic performance plays an important role in students' achievement and evaluations of academic programs. It is evident that the traditional methods of selecting students for higher institutions of learning in Nigeria have not yielded positive results, especially those on scholarships. Classifying students using traditional techniques cannot give the desired level of accuracy and may result in a waste of resources and truncation of the continuity of such generosity. Challenges deem to have caused this include the method of students' selection. However, automating this technique will be more beneficial to all parties. This research proposes a Fuzzy Logic model that will predict and classify students' performance in higher institutions according to their merit by considering some factors. The factors considered in building this model are the Ordinary (O' level), Joint Admission and Matriculation Board (JAMB) exam results, and the applicant's age. A Scikit Learn Neural Network package and a Multi-Layer Perception (MLP) classifier are chosen for the algorithm used for the implementation, while Fuzzy Logic is used as the concept. The model analysis shows that the traditional system is not the best logical approach. Rather, the use of fuzzy logic reduces the complexity and enhances the performance of selection processes while, at the same time, ensuring the best applicants get selected on merit. A good prediction of a student's success is one way to be in an education system of competition; hence the use of computing methodology is justified for its real-time applicability.*

Keywords - *Prediction, Academic performance, Fuzzy logic, Scikit learn neural network.*

1. Introduction

The main support of any country in education and a standard education could be attained in the study room [1]. Poor academic performance of students in tertiary institutions has become a concern for many, especially in developing countries like Nigeria. One of the factors attributed to students' poor performance is finance and infrastructure. Young ones (mostly teenagers) could not afford the outrageous bill to go to higher institutions, which has led to thuggery, hooliganism, dropped-out, prostitution, etc.

Other factors that cause low academic achievement in higher institutions include but are not limited to inadequate textbooks and teaching materials. Teacher factors like lateness to school, frequent absence from work, use of local language in teaching, inability to complete the syllabus, unqualified teachers, low interest in the student's understanding of the subject, and lack of dedication to duty [10], [22].

Some individual and non-profit and non-governmental organization has deemed it fit to sponsor thousands of students who cannot afford the payment of school fees into higher institutions all over Nigeria, preferably private University Institutions. It is generally believed that once the school fees are paid, students on scholarship have no reason to fail because; food and accommodation have been taken care of. The university environment is also conducive to learning, and competent lecturers are available. Making students relevant so that their performance will measure up for the money spent is of great importance to the bodies that fund them.

1.1. Statement of the Problem

With the huge amount of money for sponsoring students in the university, the quantum of money invested is no Commensurable to the performance received as feedback. Research shows that some of the challenges that may have caused this include the method of students' selection, which has been traced to be either biasness, subjectivity, or inconsistencies. Moreover, if these performances are not improved, it may likely make the system collapse.

Therefore, it is highly important to have a foresight of the future performance of students on scholarship. Hence, this research proposes to design a model that predicts and classify students' performance in higher institution putting into consideration both the previous academic performance, age, and an Intelligence- Quotient (IQ) test to find out the authenticity of the previous academic record by adopting predictive algorithms with Fuzzy Logic to serve as a determinant for awarding the scholarship to the applicants.

2. Literature Review

Based on Fuzzy Logic (FL), [2], [8] proposed a process for students' performance assessment in the university. As an input into the system, the five linguistic variables used were Very poor (VP), Poor (P), Average (A), Good (G), Very Good (VG), and Excellent (E). In this system, the fuzzy inferences used were the 'IF-THEN' fuzzy rules. The downside of this approach is that it requires a complex programming system and cannot incorporate various fuzzy platforms.

The work in [3], [11], [16] developed an academic student performance recommendation system that uses a purposeful sampling method with an in-depth technique of interview as explained in the Structure of a recommender system [3]. The Random tree algorithm was used in the study because other algorithms performed below the random tree. The optimum algorithm used in the domain of the study is the random tree. The Back-end of the Intelligent Recommender System (IRS) was generated by the rules produced from the optimum algorithm. Hence, informing the student's academic performance predictions. Below is a diagram showing the design of the recommendation system.

The work in [4], [17], [19], [20] researched two calculating subjects using the theory of fluctuating logic to identify the quantitative impacts of student performance. The principle applied to 22 First Year students taking two subjects in UNITEN Muadzam Shah. The first two subjects were tested.

The triangular membership feature was the main focus of the fuzzy logic system. Both inputs are sub-X and sub-Y, and the output is performance. The input was analyzed by MATLAB R2014a using a fuzzy logic approach to achieve the finished output. At the end of this study, fuzzy logic was found to be an important means of evaluating student performance. The result shows the output value of two inputs. Out of the 22 students, 15 were over 0.5, seven successful students were over 0.75, 7 were less than 0.5, and none were less than 0.25.

In his research, he provided a complete summary of different properties, predictive frameworks, and methods used in the educational sector for students' performance prediction was provided by [5], [21] in his research work. It was also evident how important it is to forecast student performance to various parastatals. It is to identify the attrition-risk student early enough to support him and to intervene to increase the retention and rate of performance.

Research in [6], [14], [23] compared predictive methods in a course with a standard measurement that defined students at risk of dropping out. The Ensemble model and Naive Bayes Classifier model with model sequence were found to have the best results among the test modeling methods (such as Supporting Vector Machine, Naive Bayes Classifier, and K-Nearest Neighbor).

A model that represents the student's language, in which the faculty imitates the ability of a teacher to deal with imprecise information, was developed by [7] in a Fuzzy Artmap Architectural design through Gregory L. Heileman. The key determinants in identifying successful students are different socio-demographic and study environments [12], [17], [25]. In the estimation and classify strong, moderate, and poor students, the Fuzzy ARTMAP network was used.

2.1. Suitability of Fuzzy Logic

The weakness recognized above is the essence of applying fuzzy logic [24]. For the system above, the factors can be fuzzified and combined as the aggregate; this average is then categorized and defuzzified to produce the result selection list.

2.2. Fuzzy Inference System

A fuzzy inference system formalizes or mimics the human reasoning process [8] by developing fuzzy IF-THEN rules through the use of fuzzy logic. Instead of Boolean logic, FIS uses fuzzy membership functions, linguistic variables, and rules to justify data. FIS is used to solve problems with decision-making, i.e., to reach a decision and act accordingly. Figure 1 shows how an input space is mapped to an output space by a Fuzzy Inference System (FIS).

To approach this system with fuzzy logic, the weight will be created for each of the factors; for example, the O level where all the required subject is met such student can be based on an aggregate of 5 to 30 (five subjects having A1 is 5 and five subject having C6 is 30) this weight can then be inverted as 1 for 6 and 6 for 1.

This weight can also be considered in JAMB, looking at, for example, 180 as the baseline for any student and a maximum of 400, so these will form the weight sub-grouping that can also be used like the following:

180-220 as 1
221-260 as 2
Etc

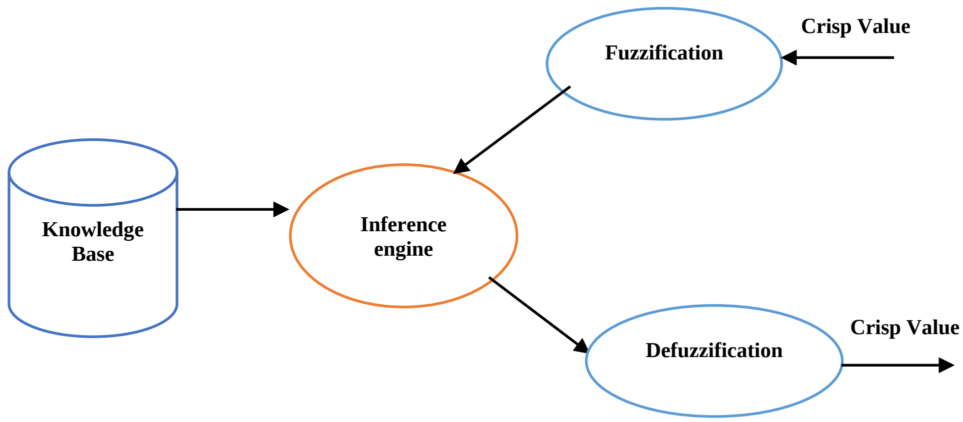

Fig. 1 Fuzzy Inference System [8]

The weight of a student can also be considered for age by inverting age; for example
On a scale of 1-10
15-17 as 10
18-20 as 2
Etc.

When all these weights are computed and the average found then, the students can then be grouped into

1. Highly Recommended
2. Recommended
3. Average (Not Certain)
4. Not Recommended
5. Highly not recommended

Using this model, the best of the students will find themselves in the category of highly recommended (i.e., students with an aggregate of 5 with about 350 – above in JAMB and within 15 - 17.

3. Methodology

There are 3 Implementation Modules presented [13]; the first module is the data gathering section where candidates submit their academic application. The second module is the inference Engine, where Fuzzy logic was used as the concept and neural networks for prediction. The third module interacts back to the user by providing the results of the analysis. The front end was built with the Angular framework consisting of HTML, CSS, and TYPESCRIPT. The angular framework uses the ASP.NET Core framework to interact with the python model used for performance prediction. The angular framework uses Typescript to make API calls to the ASP.NET endpoints, and these endpoints make API calls to the prediction model hosted online for responses. Once the response is received, results are stored in a Microsoft SQL Server database for future reference.

For the implementation of this work, a neural network algorithm was used. The python scikit learn package was used in the implementation. The python scikit learn package is a package used to perform machine learning operations. It is built off numpy, scipy, and pandas. The scikit learn library is open-source, lightweight, and free. The library was mainly selected because of the nature of the project.

3.1. System Inference and Breakdown

In developing this system, the Fuzzy algorithm will form the inference for the Artificial Intelligence (AI) engine. The Fuzzy algorithm will help classify the average weights of every student record. It will then classify the weight into one of the classes. Based on the class, a student will then be suggested for the scholarship or not suggested based on the classification. The Flow of the System Execution is depicted in Figure 2.

3.2. Algorithm Explanation

The Overall system structure follows the flowchart in Figure 2. The inference engine finds the average performance of a particular applicant in JAMB UTME and ranks it into the category of excellent, good, etc. Then the system also finds the average performance of the applicant in WAEC into categories like Excellent, Good, etc. The average performance category of WAEC and JAMB will then be combined in an inference Engine to get a stage one output before the age qualification is combined to get the output classification. The output classification will either be Suitable, Not Suitable, etc.

Considering the step-by-step flow according to the algorithm in Figure 2:

1. The system starts,
2. System prepares an environment for the user to import data into the system
3. The user imports data into the system. The data format has been well-defined and can take records of students.
4. After successfully importing data, the user can execute

the categorization, which makes the system compute the average performance for every student in a year. It will crisp input into the fuzzy system.

5. The next step is for the fuzzy logic inference to fuzzify the crisp inputs. It includes the membership functions definition.
6. The next stage is for the system to perform categorization of the output that will come out of the fuzzy inference (in this case, Excellent, Very Good, Good, Average, Pass, Fail)
7. The next stage is for the system to apply the rules using machine learning to give precise direction on the recommendations.
8. The system will then produce output
9. End

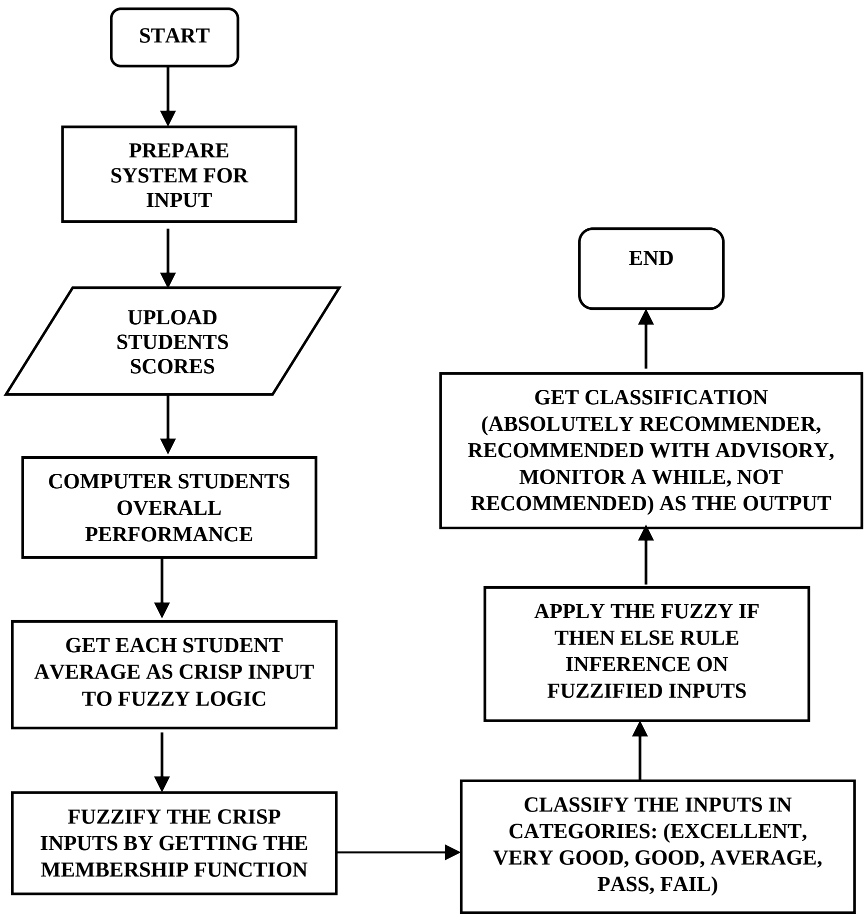

Fig. 2 Flow of the System Execution

Considering the step-by-step flow according to the algorithm in Figure 2:

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7. The next stage is for the system to apply the rules using machine learning to give precise direction on the recommendations.
8. The system will then produce output
9. End

3.3. Data understanding and preparation

The data was collected from one of the University admission units in Nigeria in a raw format. The data contains the following properties:

1. The current level of students,
2. The date of birth,
3. The WAEC scores in each subject,
4. JAMB score in each of the four subjects taken
5. The final JAMB score

4. Data Analysis and Implementation

The data was then analyzed, cleaned, and processed. Some analysis techniques include correlation, data description, data counting, and so on [9]. Missing data was also handled, and data normalization was performed (centering and scaling) of the data. Because of the need for uniformity, each student was restricted to having just 8 subjects taken in their WAEC exams. The date of birth was also converted to the age of each student, after which the date of the birth column was dropped. The scores for WAEC were also converted to numerical values (categorical variables into numerical values) as follows:

A1 = 10
B2 = 8
B3 = 7
C4 = 5
C5 = 4.5
C6 = 4
D7 = 3
E8 = 2
F9 = 0

Figures 3-6 show some data transformations before, during, and after analysis.

	Current Level	**Date of Birth (DOB)**	**WAEC Results**	**UTME Scores**	**UTME Total**
55	200	2001-06-12	Economics: C6, English Language: B3, Agric…….	English: 51, Physic: 63, Chemistry: 58.	225
56	200	2002-10-21	English Language: B3, General Math: A1, Physics…	English: 56, Physics: 47, Biology: 45…...	197
58	200	2001-05-29	Commerce: B3, Maths: C5, Accounting: B3, Econs: B2.	English: 56, Government: 64….	246
59	200	2000-07-31	Economics: C6, Biology: C6, Chemistry: B3, Math: C5	English: 43, Physics: 63, Chem...	206
60	200	2002-02-27	General Math: A1, English: C6, Biology: C6,………….	English: 49, Physics: 51, Biology: 62…….	216

Fig. 3 Initial WAEC dataset after separation from the main dataset

	One	**Two**	**Three**	**Four**
55	Use of English: 51	Physics: 63	Chemistry: 53	Biology: 58
56	Use of English: 58	Physics: 47	Biology: 53	Chemistry:39
58	Use of English: 56	Government: 64	Mathematics: 68	Ecoomics:58
59	Use of English: 43	Physics: 63	Chemistry: 45	Biology:55
60	Use of English: 49	Physics: 51	Biology:62	Chemistry: 54

Fig. 4 JAMB dataset after separation from the main dataset

	Current Level	**Waec 1**	**Waec 2**	**Waec 3**	**Waec 4**	**Waec 5**	**Waec 6**	**Waec 7**	**Waec 8**	**Jamb 1**	**Jamb 2**	**Jamb 3**	**Jamb 4**	**Age**
0	200	C6	B3	B3	B2	D7	B2	B3	B3	51	63	53	58	19
1	200	B3	A1	C4	C5	C6	A1	C5	C4	58	47	53	39	18
2	200	B3	B3	B3	A1	A1	C4	A1	C5	56	64	68	58	19
3	200	C6	C6	B3	B2	B3	B3	C6	B2	43	63	45	55	20
4	200	A1	A1	C6	B3	B3	B3	B3	B2	49	51	62	54	18

Fig. 5a WAEC and JAMB results after separating into individual cells and concatenation

		Waec 1	Waec 2	Waec 3	Waec 4	Waec 5	Waec 6	Waec 7	Waec 8	Waec 9	Jamb 1	Jamb 2	Jamb 3	Jamb 4
55		C6	B3	B3	B2	D7	B2	B3	B3	None	51	63	53	58
56		B3	A1	C4	C5	C6	A1	C5	C4	None	58	47	53	39
58		B3	B3	B3	A1	A1	C4	A1	C5	None	56	64	68	58
59		C6	C6	B3	B2	B3	B3	C6	B2	None	43	63	45	55
60		A1	C6	C6	B3	B3	B3	B3	B2	None	49	51	62	54

Fig. 5b WAEC and JAMB results after separating into individual cells and concatenation

	Current Level	DOB	UTME Total	Waec 1	Waec 2	Waec 3	Waec 4	Waec 5	Waec 6	Waec 7	Waec 8	Waec 9	Jamb 1	Jamb 2	Jamb 3	Jamb 4
55	200	2021-06-12	225	C6	B3	B3	B2	D7	B2	B3	B3	None	51	63	53	58
56	200	2022-10-21	197	B3	A1	C4	C5	C6	A1	C5	C4	None	58	47	53	39
58	200	2001-05-29	246	B3	B3	B3	A1	A1	C4	A1	C5	None	56	64	68	58
59	200	2000-07-31	206	C6	C6	B3	B2	B3	B3	C6	B2	None	43	63	45	55
60	200	2002-02-27	216	A1	C6	C6	B3	B3	B3	B3	B2	None	49	51	62	54

Fig. 6 Dataset after integrating formatted JAMB and WAEC result

5.1. Data Modeling

After the data was processed and cleaned, a scikit learn neural network package and a Multilayer Perception (MLP) classifier was chosen for the algorithm used for the implementation of the model [15], [18]. The mathematical function implemented behind the model is: ff(·): $RRmm \rightarrow RRoo$ where: m is the number of dimension input dimensions, and o is the number of output dimensions as depicted in Figure 7.

5.2. Dataset Evaluation

The model against the training dataset is depicted in Tables 1, 2, 3, and 4.

Table 1. Model against training dataset

48	0	1	0	0	0
0	1	2	2	0	0
0	0	278	17	0	3
0	0	2	253	0	0
0	0	0	5	0	1
0	0	1	0	0	22

Table 2. Evaluation Matrix for the model using the training dataset

	Precision	Recall	F1-Score	Support
	1.00	0.98	0.99	49
	1.00	0.20	0.33	5
	0.98	0.93	0.96	298
	0.91	0.99	0.95	255
	0.00	0.00	0.00	6
	0.85	0.96	0.90	23
Accuracy			0.95	636
Macroavg.	0.79	0.68	0.69	636
Weightavg.	0.94	0.95	0.94	636

Table 3. Model against the testing dataset

20	1	0	0	0	0
0	107	11	0	0	1
0	2	117	0	0	1
0	0	5	0	0	0
0	0	0	0	0	8

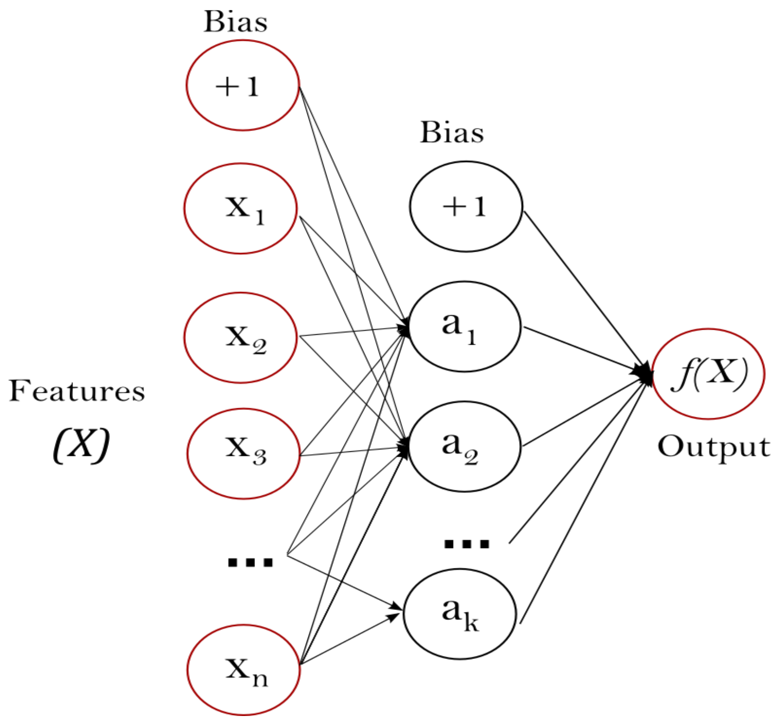

Fig. 7 The neural network image representation [23]

Table 4. Evaluation Matrix for the model using the testing dataset

	Precision	Recall	F1-Score	Support
	1.00	0.95	0.98	21
	1.97	0.90	0.93	119
	0.00	0.97	0.92	120
	0.00	0.00	0..00	5
	0.80	1.00	0.89	8
Accuracy			0.92	273
Macroavg.	0.73	0.77	0.74	273
Weightavg.	0.91	0.92	0.91	273

5.3. Results and Output

The last module of the implementation shows the results of this research work. The model results were presented in a bar chart to give the category of students according to their performances from the simulation. Figure 8 is a chart showing the result of the students according to their academic performances.

5.4. Discussion of Findings

From the findings, it was observed that for multifactor/variable systems, the traditional binary logic might not be the best logical approach. Rather the use of fuzzy logic reduces the complexity and enhances the performance. From the development of the model, it was realized that the complexity of the binary logic would be in order power of (mn) or (mna), whereas, using the concept of fuzzy logic, the complexity has been reduced to ma T where 'a' is a constant in both scenarios. It shows that fuzzy logic will greatly enhance the system's performance and reduce the cost of resources and manpower in the system development if proper knowledge and application are applied. The output of this model will serve as a determinant for awarding the scholarship to the applicants.

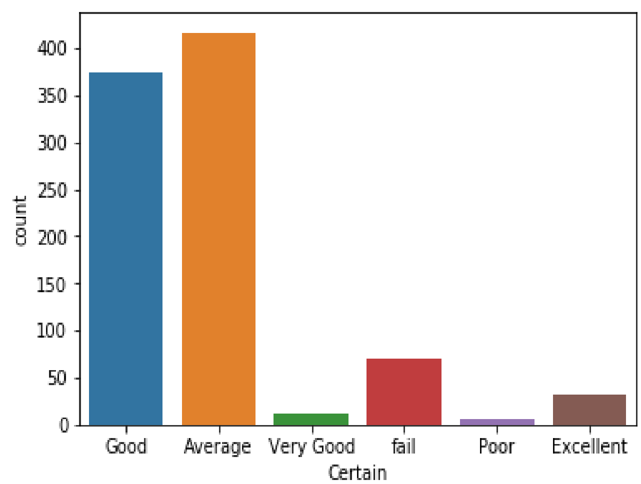

Fig. 8 Count of student Performances according to their categories

5.5. Recommendations and Limitations

Regarding the evaluation done in this study, it is expedient to ensure that individuals and NGOs wishing to give Scholarship support to students at higher institutions should adopt this new modern technique for Scholarship selection since the traditional method of selection has not been yielding a positive result when compared to their academic performances in the university. This research work has, therefore, helped identify any student that might not perform well when they get to the university; it also helps the management in decision-making by removing biasness from scholarship awardees' selection.

5.6. Contributions to Knowledge

This study has its unique contribution to knowledge because it proposes an improved method of selecting the right students to be awarded scholarships for any higher institution.

6. Conclusion

From the analysis of the model, it is evident that this model, when adopted, will be faster than the traditional method since the conventional way of selecting scholarship awardees has not been yielding a positive result in proportion to the student's academic performances in the university, which has resulted in wasting of money, time and resources, hence, limit other eligible candidate chances.

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