engineering proceedings

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Proceeding Paper

Using Fuzzy Logic for Monitoring Students Academic Performance in Higher Education †

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† Presented at the 8th International Electrical Engineering Conference, Karachi, Pakistan, 25–26 August 2023.

Abstract: Imparting quality higher education is one of the main tasks of the higher education institutes (HEIs). With advancements in teaching, learning, and assessment, new methods have evolved. In engineering education, the Washington Accord is considered a benchmark. Pakistan, through the Pakistan Engineering Council (PEC), became a full-time member in 2017. Outcome-based education (OBE) is the pivot around which this system revolves. This is a student-centric system. Student evaluation in OBE is a complicated task that involves multiple factors and evaluation mechanisms. In this research work, we have used the artificial intelligence (AI) technique of fuzzy logic for monitoring students' academic performance. From the literature, three factors, including direct assessment, indirect assessment, and stress, have been identified. The third factor stress has been added as an additional factor to gain more insight into student monitoring. Fuzzy inferencing systems using both Mamdani and Sugeno inferencing methods have been designed. The output of the system shows the comfort zone, which is satisfied evaluation; the average zone, which shows medium or acceptable evaluation; and the highly stressed zone, reflecting areas of concern where work is required to be performed to improve students' evaluation. A prototype mobile application for the system has also been developed. Results have shown that the Mamdani system performed better than the Sugeno system. The results are promising and indicate that more work is required to be executed to develop fully automated intelligent systems for students' performance monitoring and to help in achieving the United Nation's sustainable development goal (SDG) No. 4, which is quality education.

Keywords: artificial intelligence; fuzzy logic; outcome-based education; student monitoring

Citation: Jan, N.U.; Naqvi, S.; Ali, Q. Using Fuzzy Logic for Monitoring Students Academic Performance in Higher Education. *Eng. Proc.* **2023**, *46*, 21. https://doi.org/10.3390/engproc2023046021

Academic Editors: Abdul Ghani Abro and Saad Ahmed Qazi

Published: 21 September 2023

1. Introduction

Outcome-based education (OBE) is a concept that has gained popularity around the globe. The main reason is that it revolves around the learner itself rather than the tutor. According to Heywood, "Education that is outcome-based is a learner-centered, results-oriented system founded on the belief that all individuals can learn" [1].

The OBE system is a complete package of teaching learning and assessment (TLA), which has also been adapted by the Washington Accord. Because of its detailed nature, there is a need to develop intelligent systems that can help in various dimensions of OBE. However, other related areas, like stress faced by the students, have not been directly focused on in its implementation. This research focuses on using the artificial intelligence technique of fuzzy logic to develop a student monitoring system based on the OBE system for quality education, with a focus on highlighting student stress. To fulfill this task, fuzzy logic has been used, which in the literature has performed well in similar complex cases. In addition, a mobile application has also been developed to convert this research into practical applications. In this paper, Section 2 provides a literature review, Section 3 is the methodology, Section 4 gives insight into the results, and finally Section 5 is the conclusion and future directions.

2. Literature Review

In [2], authors have discussed the role of soft computing in various areas, including education. They have argued that fuzzy logic is an area of soft computing that comes under the category of approximate reasoning. They also described how fuzzy logic has been applied in the literature for evaluating students' performance in academia. They concluded that fuzzy logic can provide realistic solutions for students' assessments with variability.

In [3], authors euphuized that due to the demand by employers for skilled graduates in line with the requirements of the fourth industrial revolution, there is a need to develop intelligent automated tools that can deal with the ambiguities of the existing evaluation system for students. They highlighted that the current marking, grading, and grade point average (GPA) system is not intelligent enough to depict the actual performance of the student in education. They proposed a fuzzy logic-based system with inputs on cognitive, affective, and psychomotor domains. Two intermediate outputs were academic and personality development. The final output of the system was overall performance. For membership functions, very poor, poor, average, good, very good, and excellent memberships were used. The system was developed using Matlab R2019 and 20 students' datasets were used to evaluate the system. Results showed that the fuzzy system was able to closely match the results of the conventional system; however, the good thing was that fuzzy system results were considered more reliable. The authors concluded that more investigations are required to be performed for applying fuzzy logic in student evaluation. This research was completely based on a quantitative study of academic parameters and did not consider other aspects like stress which can adversely affect the outcome of a student.

Nowadays, mobile applications are frequently developed for software. For the current work, we have selected MIT Mobile App Inventor. This application has been used by developers in around 195 countries for mobile app development on Android and iPhone [4]. In addition, other mobile applications software are also available, which include buildfire [5], Zoho Creator [6], Mobiloud [7], etc. In the literature, authors have used MIT App Inventor to develop an application that can be used to collect and analyze sensor data [8]. In [9], authors have investigated the use of MIT app inventor by students for mobile application development and have found it a reasonable tool for application development. In research conducted on Ruse University students, it was found that students highly recommended MIT App Inventor not only to be used in the Bachelor degree program but also in the Master's degree program for mobile application development [10].

A literature review shows that monitoring student evaluation in higher education is an active research area. Also, OBE-based assessment techniques and the use of intelligent techniques are found. However, there is a need to focus on the stress factor in assessment, especially in the context of Pakistan. Therefore, in this work, we have used stress as an additional factor to provide a better insight into the OBE system. In addition to that, we also developed a basic mobile application using MIT App Inventor for the system that can be further enhanced in the future.

3. Methodology

Research methodology is shown in Figure 1. For requirement gathering, a Google Form was developed and distributed among students mainly from Balochistan UET Khuzdar, Pakistan. To obtain a general view, the form was also distributed to students outside the university. The questions were related to factors like dealing with direct assessment, indirect assessment, and stress during studies. Instead of using the data in the form of marks obtained, grades, or GPA/CGPA, the survey was conducted to find the perceptions of students regarding assessment methods and the most significant stress they faced during their studies. In response to the survey, 432 responses were received. During the survey, ethical standards were followed, no identity was shown, and complete confidentiality was ensured. The survey was conducted during COVID-19, which provided valuable results in terms of stress management for students in Balochistan during the pandemic [11]. The results of our survey showed that the students feel stressed mainly because of financial

reasons. Based on the analysis performed on the survey results, factors for the development of fuzzy inferencing system (FIS) were identified.

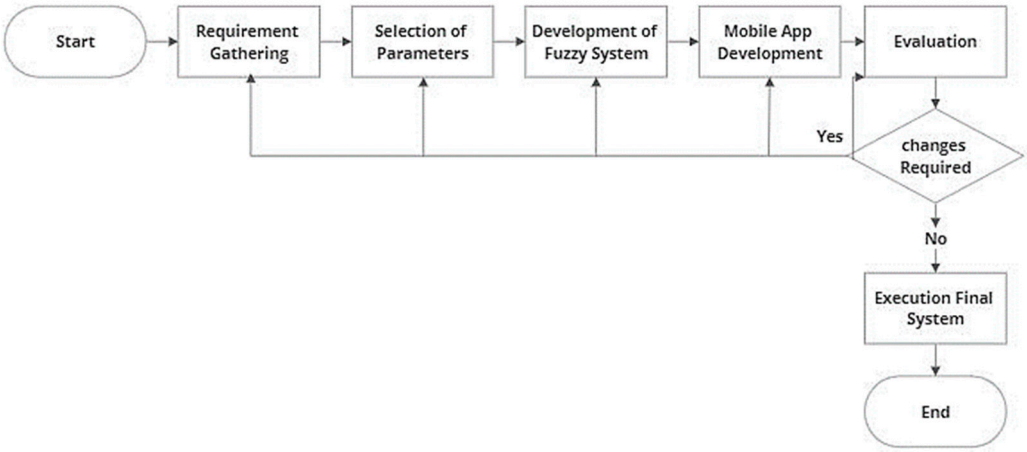

Figure 1. Flowchart of Research.

Three factors were selected as input variables from the literature review and survey results, whereas the output of the system is a consolidated assessment. The input and output variables are shown in Table 1.

Table 1. Input and Output Variables of FIS.

S. No.	Variable Name	Variable Type
1	Direct Assessment	Input (DA)
2	Indirect Assessment	Input (IDA)
3	Student Stress	Input (Stress)
4	Consolidated Assessment	Output

Development of a Fuzzy System

We have made a comparison between Mamdani and Sugeno FIS using the Matlab fuzzy logic toolbox on the selected variables for input and output. The Matlab fuzzy logic toolbox was used for the development of FIS. In the Mamdani system, each output is obtained from the output fuzzy membership function using an implication method. The final output is the result of the defuzzification process. Whereas, in the Sugeno system, output is singleton, either linear or constant, and its defuzzification method is also computationally efficient [12]. The system uses a triangular membership function, as it is the most frequently used type of membership function found in the literature. Zadeh's fuzzy inferencing scheme was used as the default. Similarly, the centroid defuzzification method was used for the Mamdani system, while a weighted average was used for the Sugeno system. A ruleset was created with the help of a combination formula for three inputs, which yields 27 rules. Output is called consolidated assessment, it also has three parameters, including comfort zone, average zone, and highly stress zone. In the Sugeno system, the values for the above-mentioned factors are given a constant value of 0, 0.5, and 1, respectively. For the Mamdani system, the same parameters were defined but using triangular membership functions.

The comfort zone shows that student performance is good and that he or she is placed at a comfortable level. The average zone shows middle-level performance, and there is a need for counseling or other steps and room for improving student performance. The highly stressed zone shows that the academic performance of students is not good, and there is a requirement to take all urgent steps so that students' academic performance can

be improved. The output of the system is envisaged to provide a guideline using artificial intelligence methods for effective student monitoring.

There are 27 rules in the system, which are the same for both the Mamdani and Sugeno systems. The rule count is based on the number of combinations possible with three variables. As it has already been established that the financial issue parameter has the highest value, which can affect student performance monitoring, the rule is that if the financial issue value is high, then the final consolidated assessment shall lie in the highly stress zone.

The developed fuzzy systems for Mamdani and Sugeno are shown in Figures 2 and 3, respectively.

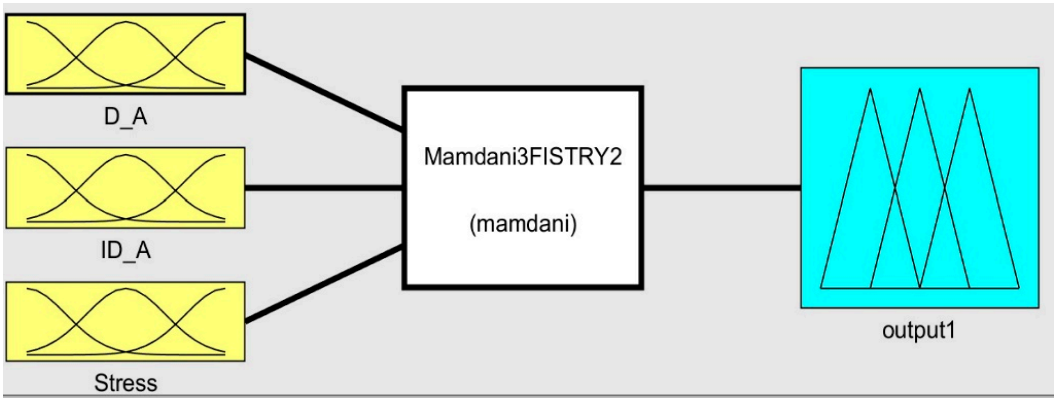

Figure 2. Mamdani FIS.

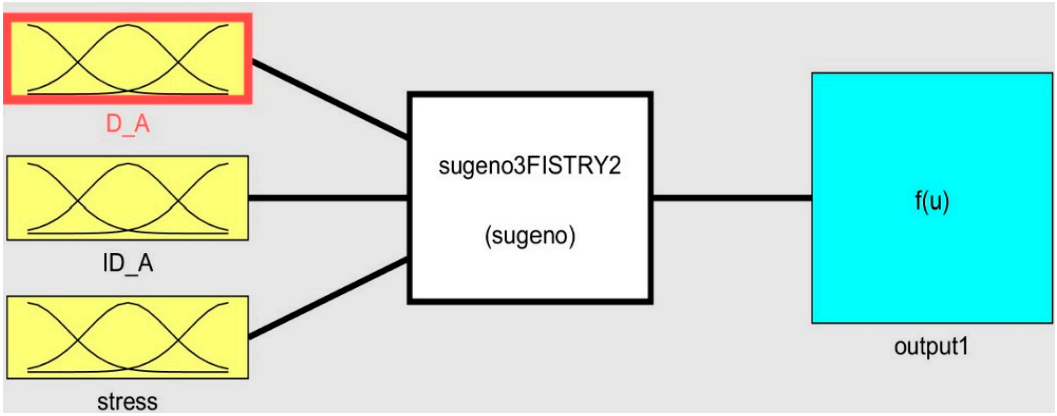

Figure 3. Sugeno FIS.

After creating the system, a mobile application was also designed to provide input and output for users using the system. This mobile application was designed using MIT App Inventor. The idea to design the mobile application was to keep in mind practical aspects of the research in terms of implementing it to contribute towards meeting the United Nations sustainable development goal (SDG) No. 4, under Vision 2030, which is related to quality education.

4. Results

For the evaluation of the project, 20 different students were selected equally for all outputs as test cases. They were divided into male and female groups. So now one group consists of 10 male student participants and 10 female student participants. The results of the group of male and female students' evaluations for both Mamdani and Sugeno systems are shown in Table 2 and Table 3, respectively.

Table 2. Result of FIS on Male Students Dataset.

Male Dataset					
S. No.	**DA**	**IDA**	**Stress**	**Mamdani Output**	**Sugeno Output**
1	10	10	90	0.86	1
2	0	10	10	0.14	0
3	30	30	10	0.45	0.44
4	15	50	20	0.45	0.5
5	90	60	40	0.86	1
6	97	45	10	0.86	1
7	17	15	0	0.30	0.083
8	23	50	5	0.49	0.5
9	3	6	5	0.13	0
10	90	98	10	0.86	1

Table 3. Result of FIS on Female Students Dataset.

Female Dataset					
S. No.	**DA**	**IDA**	**Stress**	**Mamdani Output**	**Sugeno Output**
1	10	90	5	0.49	0.5
2	40	90	15	0.51	0.58
3	60	80	40	0.64	0.833
4	65	50	10	0.52	0.58
5	65	80	90	0.84	1
6	55	40	95	0.86	1
7	15	30	75	0.53	0.68
8	25	60	70	0.56	0.67
9	45	10	91	0.86	1
10	50	65	85	0.73	0.93

It can be seen from Table 2 that the system is providing valuable information regarding the assessment of students based on the provided data. It is evident that, generally, students were able to understand the OBE system, but a number of students, because of financial stress, provided scores near 1 and were included in the highly stressed zone. Financial considerations are one of the areas that can be seen affecting student performance and need to be addressed through financial assistance in the form of various scholarships, etc. For stress related to studies, faculty coordinators can be assigned. In this way, the current system provides a guideline to improve the quality of higher education. It can also be seen that both the Mamdani and Sugeno system results were close to each other. However, the Mamdani system proved to be more sensitive, and for input, where Sugeno simply assigned zero to output, Mamdani was able to associate some values indicating the sensitivity of the system. The comparison of Mamdani and Sugeno outputs for the male student dataset is shown in Figure 4. It can be observed that both systems were able to understand the input data and, on the basis of the ruleset, were able to fire the rules.

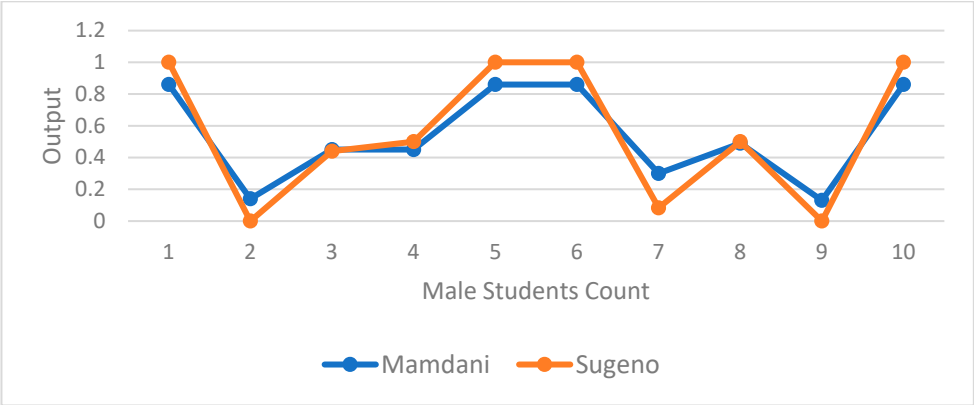

Figure 4. Comparison of Mamdani and Sugeno on the Male Students Dataset.

It can be observed from Table 3 that those female students had a different view as compared to their male counterparts. Female students were more affected by stress issues, which is why they tended to enter into highly stressed zone. Nevertheless, some female students remained in the comfort zone, and a few were in the average zone. Both the Mamdani and Sugeno systems in this case also provided compatible results, with Mamdani being more sensitive to data and firing rules accordingly. It can be seen that financial stress was high in the case of female students as compared to male students. The comparison of results for both the Mamdani and Sugeno systems is shown in Figure 5.

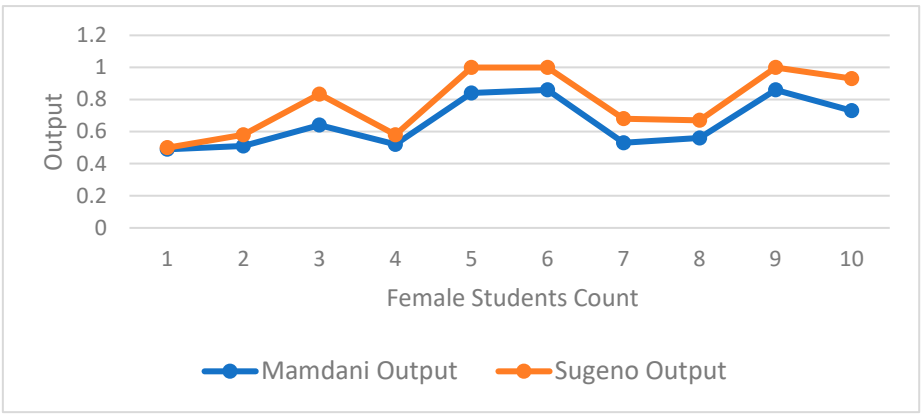

Figure 5. Comparison of Mamdani and Sugeno Systems on Female Dataset.

In the research conducted in [3], the results of the fuzzy system were on the higher side in terms of quantitative value as compared to the conventional method while using the Mamdani inferencing method only. In our case, a similar trend is observed; Mamdani provided better results as compared to the Sugeno system. It can be inferred that the Mamdani system is able to handle the complexities found in the dataset better than Sugeno and conventional systems. However, sample size also plays an important role, and more statistical testing is required to have more confidence in the results. Still, the findings of this work are consistent with similar research conducted in the past in this area. The results can be used to monitor student performance and provide remedies for complications related to students' performance, emphasizing the stress factor.

5. Conclusions and Future Work

In our current work, we have used fuzzy logic to create a student monitoring system in higher education. For this purpose, we identified three input variables, namely direct assessment, indirect assessment and stress, through a survey conducted online. These input variables were used to create a FIS comparing both the Mamdani and Sugeno methods.

Independent datasets were used to test the system. The output of the system was comfort zone, average zone and a highly stressed zone. The results showed that the Mamdani system was able to perform well as compared to the Sugeno system. We also prepared a prototype basic mobile application that can be used for giving input to the system and extracting output from the system. Results are promising, and there is scope for further work to be carried out in this regard to have a real-time monitoring and guidance system for students in higher education paradigms, including OBE and variable factors like stress covered in this research. In the future, other artificial intelligence techniques like deep learning recommender systems, etc., can be used to develop such real-time systems.

Author Contributions: Conceptualization, S.N. and N.U.J.; methodology, S.N.; software, N.U.J.; validation, S.N., N.U.J. and Q.A.; formal analysis, S.N.; investigation, N.U.J.; resources, S.N. and Q.A.; data curation, S.N.; writing—original draft preparation, S.N. and N.U.J.; writing—review and editing, S.N., N.U.J. and Q.A.; visualization, N.U.J.; supervision, S.N.; project administration, S.N.; funding acquisition, S.N. All authors have read and agreed to the published version of the manuscript.

Funding: This research work is supported by Balochistan University of Engineering and Technology, Khuzdar, Pakistan, and Ignite NGIRI funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Written informed consent was obtained from the students involved in the study.

Data Availability Statement: Customized data set not yet publicly available.

Conflicts of Interest: The authors declare no conflict of interest.

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