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# An Intelligent Tool Based on Fuzzy Logic and a 3D Virtual Learning Environment for Disabled Student Academic Performance Assessment

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**Abstract:** In a virtual learning environment, it is important to be able to correctly assess students to help them receive the best possible education. This can have a big impact on the way disabled students learn and their goals for gaining a high level of qualification. This paper investigated different fuzzy logic-based techniques for student academic evaluations in a 3D virtual learning environment (VLE). Some of the techniques were found to be especially helpful for disabled students, and the paper also described the development and design of evaluation systems that take this into account. The study used fuzzy logic to study how well disabled students are doing in their classes over a whole year. This fuzzy logic was developed using MATLAB software, which uses features extracted from student evaluations. Disabled students' characteristics (such as experience and understanding, problem-solving skills, etc.) have been measured and combined with a 3D virtual learning environment built using open-source software, Moodle, and Sloodle. This way, disabled students can interact with their courses inside a 3D VLE using Sloodle. According to the findings, which were based on 20 disabled students, fuzzy logic technology used in 3D Virtual Learning Environments (VLEs) produces different results than traditional assessments. The difference between the two is about 3.9 points on average.

**Keywords:** student assessment; 3D VLE; doodle; moodle; metaverse; fuzzy logic; disabled students



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## 1. Introduction

University education is focused on assessing a student's potential to succeed in their academic studies. This assessment looks at a student's predicted academic achievement and then focuses on teaching them the skills and knowledge they need to achieve the level of success that was predicted [1]. Evaluation is a way for teachers to get information about how well students are doing in school. This information can help teachers make sure that students are getting the most out of their education [2]. The assessment process begins by identifying what students need to learn to achieve their goals. Then, a judgment is made to see if those goals have been reached [3]. The current study looked at how well students with disabilities did in their academic classes. Then, the researchers decided if the students met the goals, they had set for themselves. Evaluation is an important part of learning, and everyone involved in it, including students, teachers, and colleagues, should be careful when making evaluations [4]. Even if a student does not do as well as others in the learning process, they may still be able to succeed. Fuzzy logic better evaluates student performance and can be applied for aptitude testing, recruitment procedures, skill-based certification, and experimental learning [5]. The idea is that if we use assessment methods that show what students have learned and what they need to continue learning, students will be more likely to take the assessments seriously. This will help us to know what we need to do to help students learn more effectively [6]. Through the assessment process, institutions are looking at many different skills, such as problem-solving skills,

communication, and group-work skills. They are also looking at behavioral attitudes, lab performance, project analysis skills, and more [7]. To evaluate these criteria, different ways of calculating statistics and arithmetical methods based on approximate data have been used. This approximation arises from the teachers' interpretation of student performance. Nowadays, reasoning based on fuzzy logic is used as an alternative way of handling data that are not very precise [7,8].

Virtual worlds are programs that let you create a virtual environment that looks and feels like the real world. You can use these worlds to play games, explore new places, and meet new people. You can even create virtual characters called "avatars" that represent you [9]. Teachers need to be familiar with virtual environments so they can improve students' performance in educational activities. Virtual environments cannot do things like manage students' records or track their activities, but they can be used to deliver educational activities. The next trend in e-learning is to integrate virtual worlds with learning management systems so that teachers and students can work together more easily [9]. A virtual teacher is a type of teacher who helps students learn by using technology. They may use things like virtual headphones, smart glasses, or applications to help manage their classroom remotely [10]. One big advantage of learning in a virtual learning environment (VLE) is that you can get help and support as you learn. VLEs let you learn in a way that is different from traditional classrooms, and they can be especially helpful when it comes to building knowledge and integrating what you are learning into the virtual world. Additionally, VLEs make learning interactive and fun, which can help you retain information better. Finally, VLEs can be used in web platforms, which makes them very versatile [10]. This means that you can use different learning methods to learn more effectively, including using VLEs and learning systems (LSs). This makes it possible for developers and educators to find new ways to learn in online platforms and multi-user virtual environments (MUV) [10]. A virtual learning environment is a way to provide total learner immersion, which is especially helpful for students with disabilities. It helps them learn better in any institution, even if there are many students without disabilities. VLEs are very well-received by everyone, especially disabled students. A VLE is cheaper and easier to use than traditional learning methods, encourages learners to participate more actively, and allows them to learn and study in any location [9,11]. In this paper, we describe a new way of assessing students with different disabilities in a virtual reality world that provides complete immersion for the students. This system will help disabled students to better their performance in any institution by evaluating themselves and correcting their errors and weaknesses, even if they don't have the same disabilities.

This paper introduces a new way of assessing students with different disabilities that can be used in a virtual learning environment in Section 1. The study looked at how well students with disabilities did in their academic classes. Section 2 discusses the literature review, Section 3 discusses related work, Section 4 described the method of the proposed system with hypotheses of the study as well as the architecture of the proposed system, Section 5 explains the experimental results and discussion for the proposed system, and Section 6 discusses Defuzzification and Experimental Results. Section 7 concludes the paper.

## 2. Literature Review

### *2.1. Fuzzy Logic*

Fuzzy set theory is a kind of set theory that is both continuous and fuzzy, which means that there are no clear boundaries between sets in this theory. This theory is used to demonstrate human knowledge and justification [12]. Fuzzy logic is a way of taking input from things like words and numbers and transforming them into a more understandable form. This is done by using a system of rules that can change as new information is input. Finally, a numerical calculation is performed using the fuzzy labels that were created initially [13]. Fuzzy logic is a way of thinking about things that is a little less strict than traditional logic. It works by considering both the true and false aspects of a situation,

rather than just deciding one way or the other; and because fuzzy logic is systematic, it can deal with the concept of partial truth, which means there can be a range of possible outcomes that are all considered true [14]. Fuzzy logic is a way of thinking about things that is a little bit like thinking about numbers that are a little bit like clouds. It is a way of looking at things that uses a kind of logic that is based on the principles of a fuzzy set. When we use fuzzy logic, we are talking about a situation where the truth value of a complex logical proposition is determined by the truth value of its components, and the degrees of truth for each of those components can vary from 0 to 1 [15]. For example, through the use of computation, the proportions of the ingredients in a concrete mixture are determined based on expert judgment and information about mix design formulations. This is then used to create an intelligent model with a high level of prediction accuracy [16].

### 2.2. Fuzzy Inference System (FIS)

A fuzzy inference system (FIS) is a decision-making system that uses fuzzy logic rules to generate crisp output results. It takes input data and processes them according to specific rules to generate outputs. The outputs and inputs are real-world values, while the processing system is based on fuzzy arithmetic. Fuzzy inference is the process of formulating input and output mappings using a fuzzy logic system and its operation is shown in Figure 1 below.

- Fuzzification

This function matches up the pieces of input data sets to determine which series of membership functions best describes them. This allows the 3D VLE to map input values from 3D VLE to a range from 0 to 1. This process is useful for translating crisp input data into more meaningful linguistic variables [16].

- Fuzzy rule base

In a fuzzy logic system, there are no specific model parameters or mathematical equations required—all constraints, model complexity, and non-linear relationships are incorporated in the fuzzy inference setup as IF-THEN statements. This makes the system more flexible and easier to use, since it can consider a wider range of possible fuzzy relationships between input and output data sets [16].

- Fuzzy inference engine

The fuzzy inference engine helps to simulate the reasoning process of a human being by evaluating the inputs and using the IF-THEN fuzzy rules. It considers all of the rules in the fuzzy rule base and then learns to transform sets of input variables into output results [16].

- Defuzzification

The fuzzifier helps to make the fuzzy outputs of the decision-making unit or inference engine more precise. This is done by using membership functions that approximate the ones used by the decision-making unit or inference engine itself [17,18].

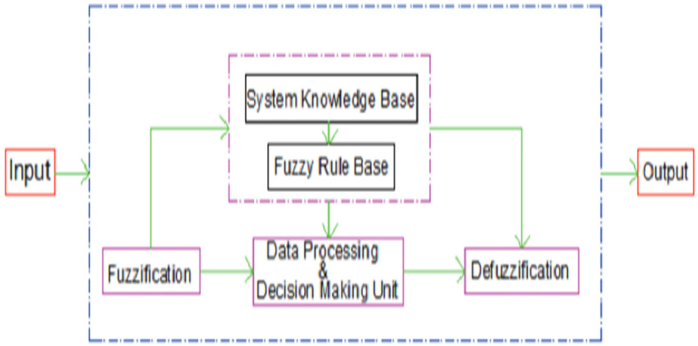


**Figure 1.** Components of the fuzzy inference system.

### 2.3. Types of Fuzzy Inference Method

- Mamdani FIS

The Mamdani Method uses only two input variables and one output variable. This fuzzy inference system represents the consequences of a fuzzy rule in the form of "if-then" statements. The output variable is divided into fuzzy sets, and the surface that represents the non-continuous relationship between the input and output variables is created [19].

- Sugeno FIS

The Takagi–Sugeno–Kang method is a way of making decisions about things that are not clear or definite. In the first and second stages, you fuzzify your input data and then use fuzzy operators to create a decision. However, the Takagi–Sugeno–Kang method is different from the Mamdani method in that the membership functions of the output variables are either constant or linear [20].

## 3. Related Work

There is little research on how to assess students in 3D virtual learning environments (3D VLEs). However, most of the research on predicting learning styles in e-learning environments is based on studies of 2D learning environments. ALAM, A., et al. developed a system that helps students progress through different levels of learning by transitioning to different pathways. Fuzzy logic makes the approach more realistic and efficient, helping students who are struggling to improve gradually while providing an opportunity for a good student to make quick progress. This motivates students to learn, which results in improved learning in virtual learning environments [5]. The Eryılmaz, Adabashi FB-ITS study is designed to help students learn more effectively in a classroom setting. The system uses artificial intelligence methods based on fuzzy logic and Bayesian networks to learn how students are performing and make appropriate adjustments accordingly [21]. In Wardoyo and Yuniarti's study, researchers looked at how fuzzy logic can be used to improve the assessment of Algorithm and Data Structures courses in e-Learning. This could help students learn more effectively, and help instructors better assess the student's progress [22]. In a study by I. Matazi, A. Bennane, R. Messoussi, and R. Touahni, a Multi-Agent System (MAS) was created using fuzzy logic to assess the level of learner collaboration. This system takes input from learning path analysis on online collaborative learning platforms (LMS) [23]. In their study, Hanna, N., Richards, D., and Jacobson, M.J. looked at how different types of learning (in a virtual classroom) impact a student's academic achievement. They studied how much time students spend in the virtual classroom, how well they learn, and how this relates to their final academic achievement [24].

## 4. Method

In this paper, we are investigating how well fuzzy logic can help us evaluate student achievement in a virtual learning environment. We use the scores from student assessments that are based on abilities or student achievement. There is already research on fuzzy logic in student performance, and we use virtual learning tools to help students learn more interactively. We embed the tools in a 3D object, and then disabled students can interact with it by touch. This sends an HTTP request to a fuzzy inference system that is programmed using MATLAB and is available as a web app to assess disabled students.

### 4.1. 3D Virtual Learning Environment (3D VLE)

The authors are proposing to create a 3D Virtual learning environment that can be used to assess the academic performance of students with learning disabilities. This assessment process will be done using an intelligent system that uses fuzzy logic methods. A system must provide the necessary technology and tools to incorporate an emulator of the 3D virtual learning environment (OpenSim) that is used to simulate it. Connecting the virtual environment with the learning management system, Moodle, would allow students to manage the latter from inside the virtual learning environment [10]. The application was

very well-received by students in general, and especially by disabled students. It helped to reduce the cost of studying and teaching, encouraged learners, and offered opportunities to learn and study in any location [10]. The proposed intelligent system would allow residents of the environment to communicate with each other by voice chat and SMS messages. They can also receive calls from people outside the virtual community [10]. The virtual learning environment provides opportunities for people with disabilities to live and work in the same community as everyone else. They can socialize with other residents, participate in individual and group activities, and create virtual properties and services. These benefits are specific to people with disabilities, so they can have a better integration into normal life [10].

We will configure the learning management system to work with SLOODLE tools by copying and pasting SLOODLE-configured files into it. Then, we will create and design the 3D primitive shapes used for experiments. Finally, based on the characteristics of the experiment, we will write LSL scripts to program each object [10,25].

### 4.2. Our Proposed System

The major weakness of current achievement assessment methods is that they do not provide enough information about the tools used to measure student achievement in the past. A proposed approach to assessing a disabled student's performance would involve using a fuzzy approach [12,13]. The idea is that a disabled student's achievement should be assessed based on their complete abilities, no matter what their level or test scores are in their Moodle profile. The model for assessing disabled students' performance in a 3D VLE includes knowledge, participation, and attendance as well as experimental work. These are some of the input variables. Inputs into the proposed system are student evaluations. Fuzzy logic was developed using MATLAB software (https://www.mathworks.com/products/matlab.html, accessed on 10 April 2023), which uses features extracted from student evaluations and combined with a 3D virtual learning environment (VLE) we designed using Open Simulator. This environment is based on a 3D virtual world and simulation of the real-world environment, we used (Sloodle) technology to connect our 3D virtual learning environment to a learning management system (Moodle) so that we could manage students' activities, tests, and exams. This environment is ideal for storing educational content because it is safe and secure [10,25]. A jar file is created in MATLAB Builder NE, which is then used to call a web-based application that integrates the fuzzy inference system with the 3D VLE. The requirements for this project called for a flexible design, so the system included three components: the Open Simulator, which allows us to create, design, and emulated a virtual educational metaverse; Sloodle technology, which connects the metaverse to Moodle; and Moodle, which is a software used in educational institutions. Using Sloodle technology, students with disabilities and their teachers can access Moodle materials and activities [10]. Finally, we have assessment fuzzy logic inference which does the assessment process.

Figure 2 presents in detail the model proposed in our approach. It is made up of open-source software that is used in educational institutions. One part of the proposed intelligent system links the names of students with disabilities, including those with motor disabilities, hearing impairments, hyperactivity, dyslexia, dyscalculia, etc., and their teachers. This is done through email services. The system also uses Sloodle technology, which makes it possible for students with disabilities and their teachers to access materials and activities on Moodle. The system was designed practically, with access to the various technical tools and Sloodle management systems available in the metaverse. Figure 3 shows a virtual learning environment with SLOODLE for disabled students, which allows them to access educational content with different quizzes, activities, and exams. This helps to later assess their performance.

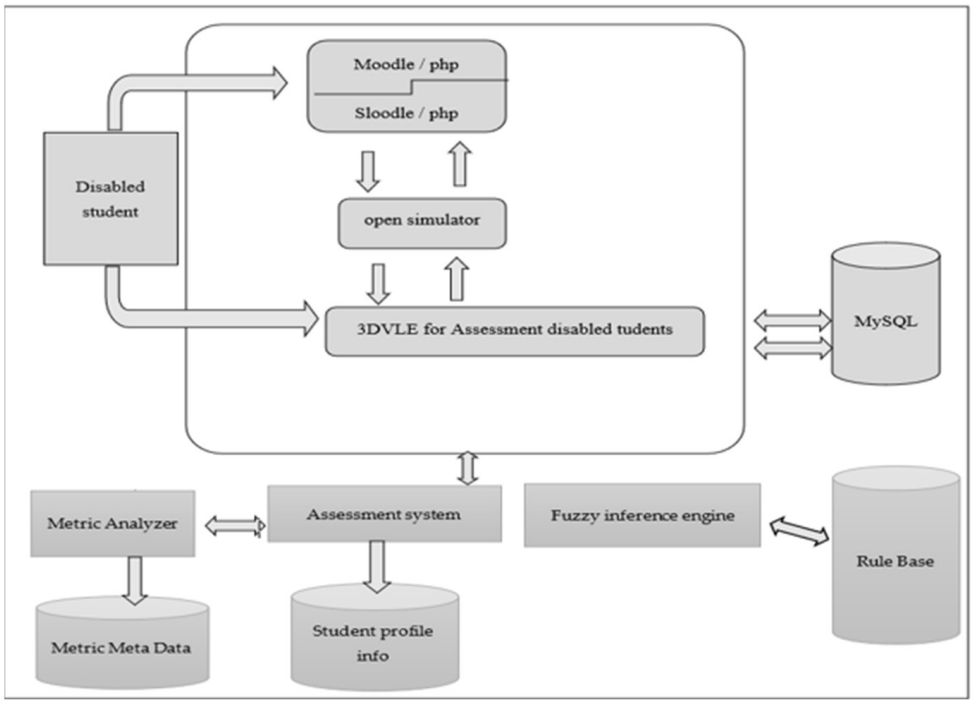


**Figure 2.** Proposed model for assessment of disabled students' performance in 3D VLE.

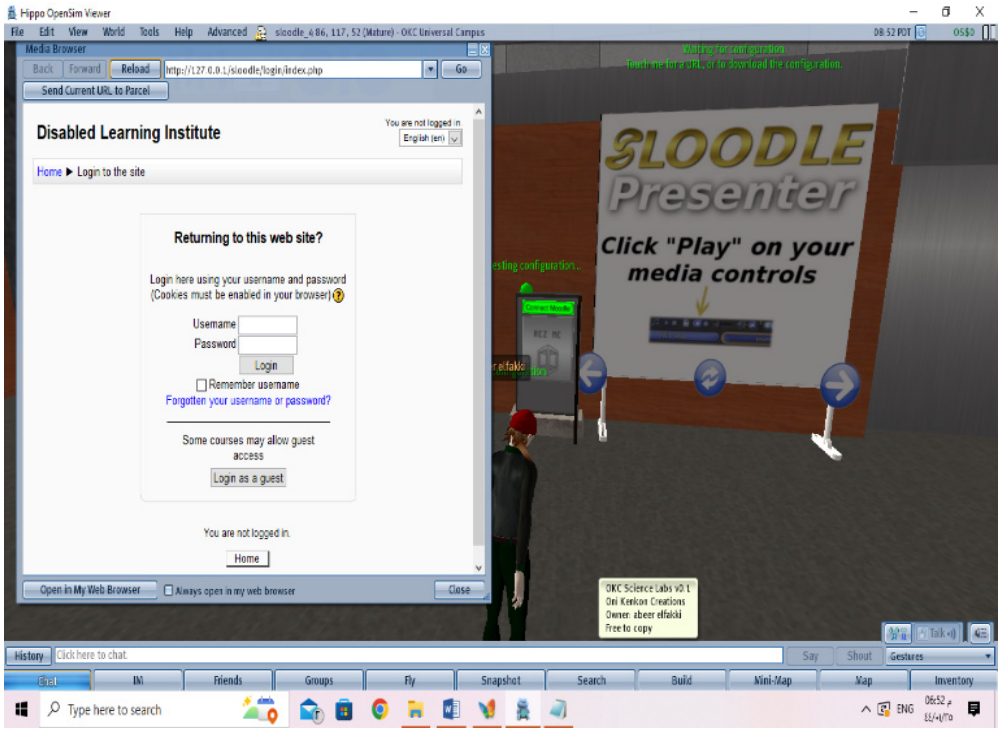


**Figure 3.** 3D virtual learning environment with SLOODLE.

Figure 4 presents a MATLAB Webapp for the assessment of disabled students in the 3D VLE.

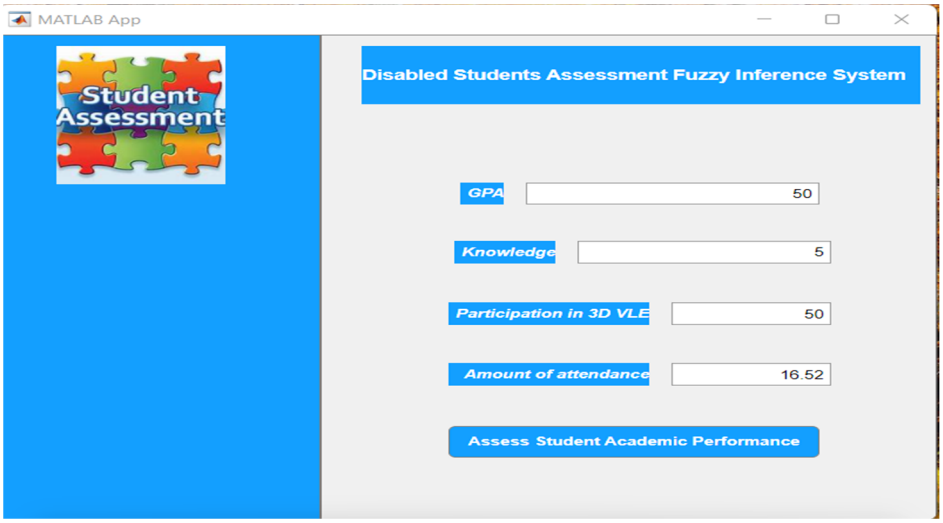


**Figure 4.** MATLAB Webapp user interface.

The new approach would give teachers more information when making important decisions about their students. Table 1 illustrates the connection between different aspects used to evaluate participants' educational achievement and personal character development.

**Table 1.** 3D VLE FIS input and Output Variables.

| Input | Attribute | Output |
|---|---|---|
| GPA | Disabled student Grade | Disabled student Assessment |
| Knowledge | Grade (quizzes) | |
| Participation in 3D VLE | Message (opinion post in 3D VLE) | |
| Amount of attendance | Action time of: (created, accepted, reviewed, searched, shown, started, submitted, updated, uploaded, interact with a 3d object during learning and 3D VLE navigation) | |

### *4.3. Fuzzy Inference System Proposed Process*

Inputs and Outputs of the Proposed Fuzzy Logic System

Input variables help to influence student performance on a test. These include things like how well students have studied, what they have learned, and how often they have participated in class. The final output variable is how well students do on the test. The knowledge variable can be measured on a scale from 0–100. The parameter point total for participation is based on how many comments are submitted in the scope in which we can measure it. The range is [0–20]. The student enrollment parameter score on a scale of 0–100 is how long the students spend in the system, ranging from 0 to 4000 min. The disabled student achievement variable measure indicates how well the students are doing. The 3D VLE database is the data source. Table 1 lists the attributes, tables, and data separation processes used to get the input variables. The attendance data was preprocessed to yield 18,488 records. There are several different activities students can do during their time in the 3D VLE. This information was used to calculate how much time they spent doing each activity. Then, statistics for different knowledge and participation variables were collected from the Moodle testing and examination results tables. Finally, data about what students were saying and posting in the 3D learning environments was extracted. The fuzzy rule base and the fuzzy input value from the fuzzifier help generate a fuzzy output value [7,26,27]. The fuzzy value is converted by the defuzzifier into a clear value. This

process helps to measure a student's academic success. Figure 3 illustrates this fuzzification process.

The fuzzy inference system in Figure 5 uses four different inputs to work out how a disabled student is performing. Based on that information, the system produces one output—whether or not the disabled student is performing well.

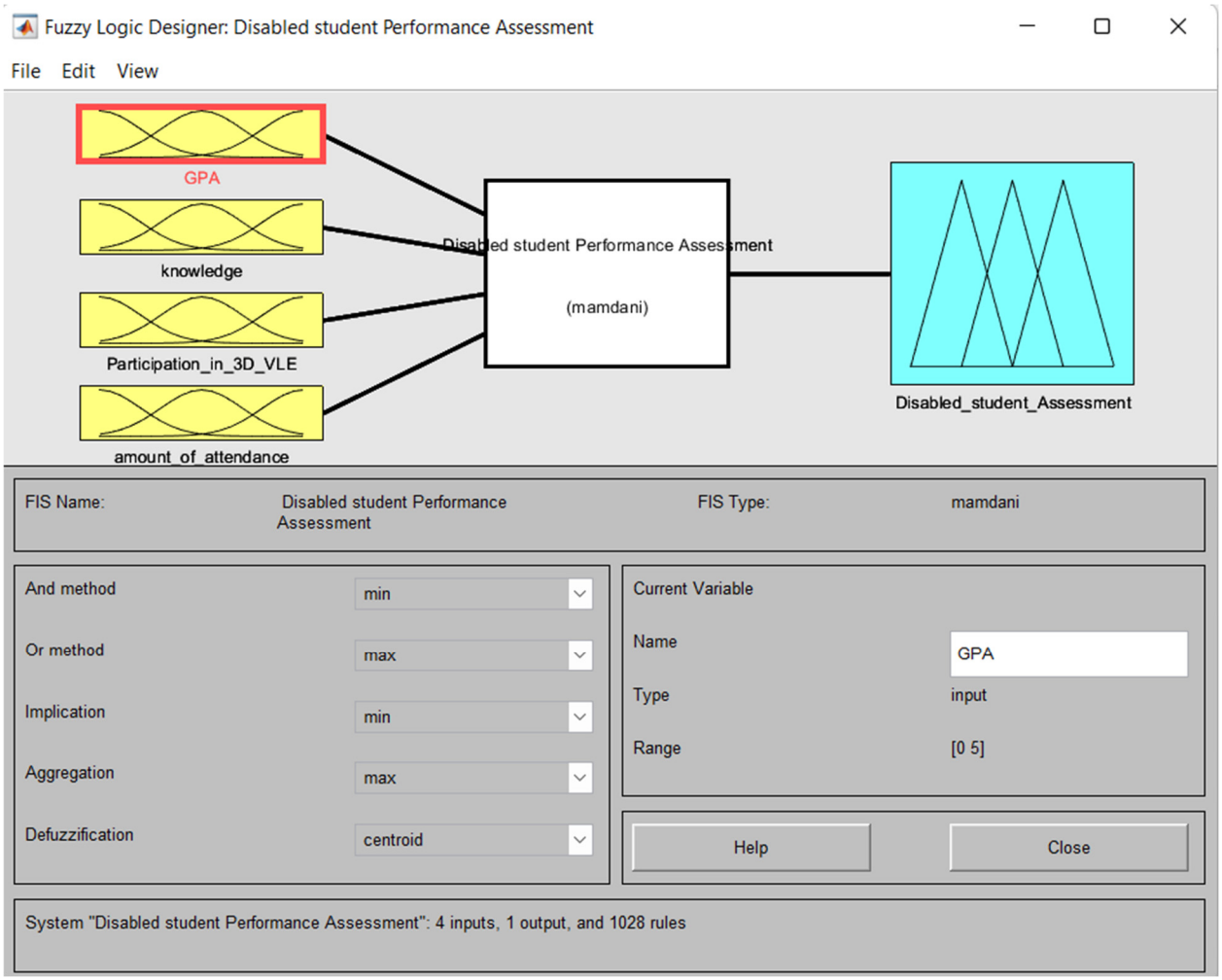


**Figure 5.** A Fuzzy Inference System.

## 5. Results and Discussion

### *5.1. Fuzzification*

Semester grades were fuzzified using input variables and their membership functions. For each disabled student, the GPA results in input variables had four membership functions: "low", "average", "good", and "very good" [26]. Tables 2 and 3 show the results.

**Table 2.** Fuzzy set of inputs GPA Result.

| Linguistic Term | Signifier | Periods |
|---|---|---|
| Low | L | (0, 0, 2.0, 3.0) |
| Average | A | (1.5, 2.0, 3.0, 3.5) |
| Good | G | (3.0, 3.5, 4.0, 4.17) |
| Very good | VG | (3.5, 4.0, 4.5, 4.5) |

- Fuzzification of Knowledge: the linguistic variable "Knowledge" represents the scope [0, 100] exam results. There are four classifications of linguistic terms for knowledge: low, average, good, and very good [26]. Table 3 summarizes the input variables, signifiers, and periods for linguistic terms knowledge. The linguistic term "average", for instance, has a scope of [30, 80], with 30 as the lower bound and 80 as the maximum bound.

**Table 3.** Fuzzy set of input knowledge.

| Linguistic Term | Signifier | Periods |
|---|---|---|
| Low | L | (0, 30) |
| Average | A | (10, 70) |
| Good | G | (30, 75) |
| Very good | VG | (70, 95) |

The membership function in Figure 6 tells us how many disabled students are in a group based on their knowledge of a certain topic.

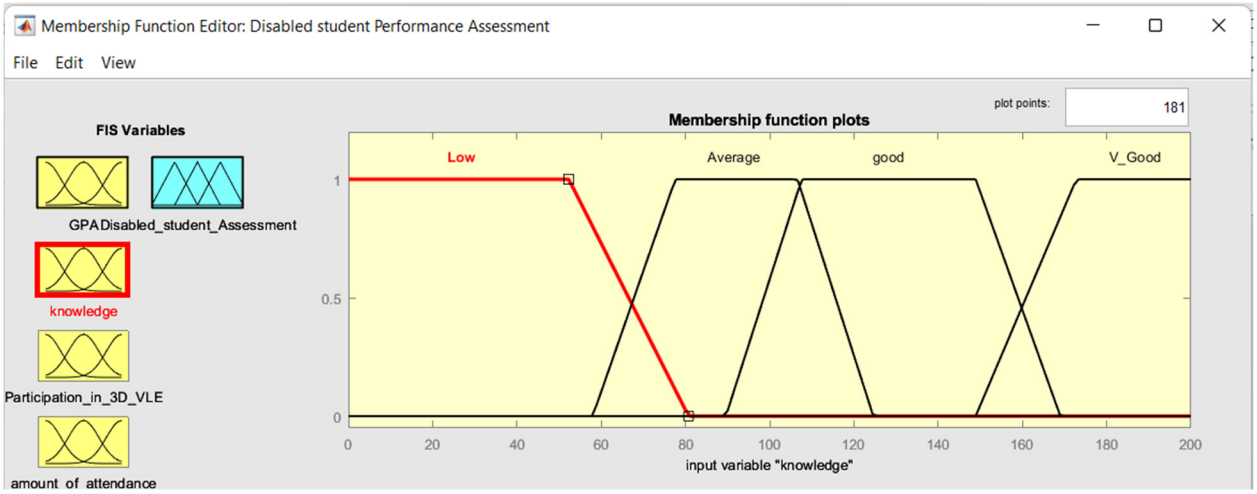


**Figure 6.** Input Variable knowledge.

- Fuzzification of participation in the 3D VLE: The linguistic term "participation in 3D VLE" signifies the number of student comment posts and has the scope [0, 10]. Participation in a 3D VLE has three different sets of linguistic variables, such as low, average, good, and very good [26]. The input variables, signifiers, and periods for the fuzzy linguistic amount of attendance are described in Table 3. For instance, the verbal term "average" is in the period [7,26], where 4 is the lower bound and 8 is the upper bound of the number of comment posts. The input parameters follow fuzzy set theory. Figure 4 shows the available membership function.
- Fuzzification of attendance: The linguistic term "amount of attendance in minutes" corresponds to the entire disabled student's time of the tasks throughout the framework and has a scope of [0, 4000]. The fuzzy linguistic attendance is divided into four sets of aspects: low, average, good, and very good [7,26]. Table 4 displays the input variables, signifiers, and periods for fuzzy linguistic attendance. The term "linguistic average", for instance, falls within the scope [1001, 3001], where 1001 min is the lowest bound and 3001 min is the highest bound for overall activity time.

**Table 4.** Fuzzy set of input Participation in 3D VLE.

| Linguistic Term | Signifier | Periods |
|---|---|---|
| Low | L | (0, 6.0) |
| Average | A | (4.0, 8.0) |
| High | H | (6.0, 10.0) |

Table 5 presents a set of input amount of attendance (signifier and periods) in the linguistic term.

**Table 5.** Fuzzy set of input amount of attendance.

| Linguistic Term | Signifier | Periods |
|---|---|---|
| V_Low | VL | (0, 0, 1000) |
| Low | L | (250, 2000) |
| Average | A | (1000, 3000) |
| Good | G | (2000, 3750) |
| Very good | VG | (3000, 4000) |

- Fuzzification of Student Performance as a Whole: The linguistic variable "student performance" represents student performance scores with a domain [0, 100]. Poor, average, good, and very good are the linguistic terms for the linguistic variable of student performance.

  Table 6 presents a set of output of the assessment of disabled students.

**Table 6.** Fuzzy set of the output of disabled student assessment.

| Linguistic Term | Symbol | Periods |
|---|---|---|
| Low | L | (0, 0, 40) |
| Average | A | (20, 60) |
| Good | G | (40, 80) |
| Very good | VG | (60, 75) |
| Excellent | E | (80, 100) |

Figure 7 shows how the Disabled Student Assessment as a Whole.

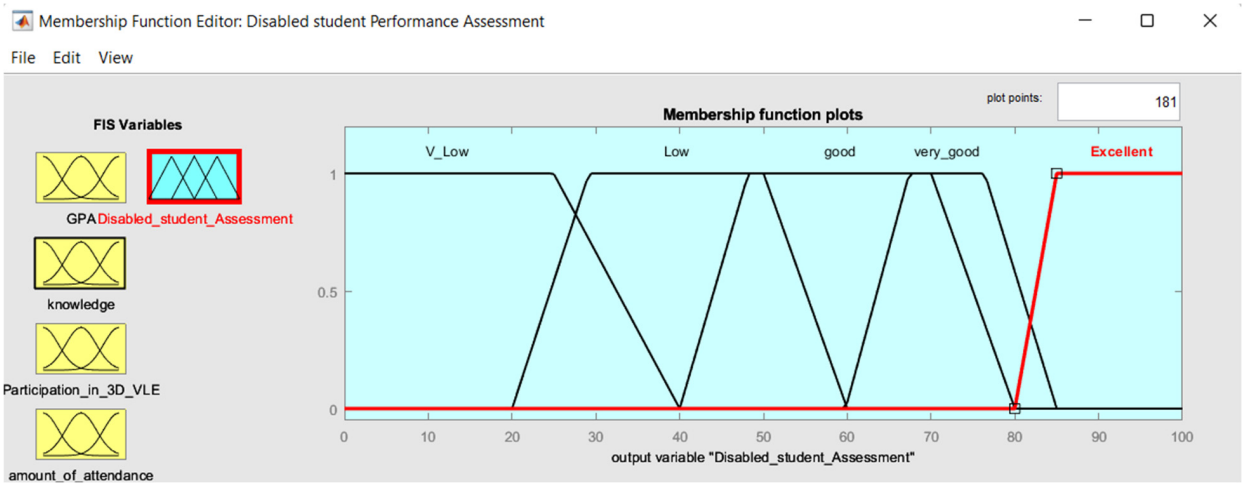


**Figure 7.** The Output of the Disabled Student Assessment as a Whole.

### *5.2. Fuzzy Rule-Based*

A fuzzy expert system is one in which rules are knowledge that is constructed by meeting all constructs meaningful and universally. Every fuzzy rule in a fuzzy inference system has two parts: IF expresses the antecedent part (premise) and THEN expresses the subsequent part [16]. The Mamdani algorithm's general IF-THEN structure is shown in (1).

$$R_i : if\ x\ is\ A_i\ and\ \ldots\ then\ y\ is\ B_i\ (for\ i\ =\ 1,\ 2,\ 3,\ \ldots,\ K) \quad (1)$$

In a rule-based fuzzy logic system, there are a total of 240 rules. Each rule has a number, Ri, and refers to a fuzzy set, Ai, and a fuzzy set, Bi. After a fuzzy system's outcome is determined, y is after that same fuzzy system's outcome, and x is the input in the fuzzy inference system as shown in Figure 8.

Fuzzy Inference System (FIS) Plot | Membership Function (MF) Editor | Rule Editor

System: Disabled student Performance Assessment

Add All Possible Rules | Clear All Rules

| | Rule | Weight | Name |
|---|---|---|---|
| 1 | If GPA_1 is Low and GPA_2 is Low and knowledge is Low and Participation_in_3D_VLE is Low and amount_of_attendan... | 1 | rule1 |
| 2 | If GPA_1 is Low and knowledge is Average and amount_of_attendance is Average then Disabled_student_Assessment is... | 1 | rule2 |
| 3 | If GPA_1 is Average and knowledge is Average and amount_of_attendance is Average then Disabled_student_Assessme... | 1 | rule3 |
| 4 | If GPA_1 is Low and knowledge is good and amount_of_attendance is Good then Disabled_student_Assessment is very... | 1 | rule4 |
| 5 | If GPA_1 is good and knowledge is good and amount_of_attendance is Good then Disabled_student_Assessment is very... | 1 | rule5 |
| 6 | If GPA_1 is Low and GPA_2 is V_good and knowledge is V_Good and Participation_in_3D_VLE is V_Good and amount_... | 1 | rule6 |
| 7 | If GPA_1 is Average and GPA_2 is Average and knowledge is Average and Participation_in_3D_VLE is Average and amo... | 1 | rule7 |
| 8 | If GPA_1 is Average and GPA_2 is Good and knowledge is Average and Participation_in_3D_VLE is Good and amount_... | 1 | rule8 |
| 9 | If GPA_1 is good and GPA_2 is Good and knowledge is Average and Participation_in_3D_VLE is Good and amount_of_a... | 1 | rule9 |
| 10 | If GPA_1 is Low and GPA_2 is Low and knowledge is Low and Participation_in_3D_VLE is Low and amount_of_attendan... | 1 | rule10 |
| 11 | If GPA_1 is Low and GPA_2 is Low and knowledge is Low and Participation_in_3D_VLE is Low and amount_of_attendan... | 1 | rule11 |
| 12 | If GPA_1 is Low and GPA_2 is Low and knowledge is Low and Participation_in_3D_VLE is Low and amount_of_attendan... | 1 | rule12 |
| 13 | If GPA_1 is Low and GPA_2 is Low and knowledge is Low and Participation_in_3D_VLE is Average and amount_of_atte... | 1 | rule13 |
| 14 | If GPA_1 is Low and GPA_2 is Low and knowledge is Low and Participation_in_3D_VLE is Average and amount_of_atte... | 1 | rule14 |
| 15 | If GPA_1 is Low and GPA_2 is Low and knowledge is Low and Participation_in_3D_VLE is Average and amount_of_atte... | 1 | rule15 |
| 16 | If GPA_1 is Low and GPA_2 is Low and knowledge is Low and Participation_in_3D_VLE is Average and amount_of_atte... | 1 | rule16 |
| 17 | If GPA_1 is Low and GPA_2 is Low and knowledge is Low and Participation_in_3D_VLE is Good and amount_of_attenda... | 1 | rule17 |
| 18 | If GPA_1 is Low and GPA_2 is Low and knowledge is Low and Participation_in_3D_VLE is Good and amount_of_attenda... | 1 | rule18 |
| 19 | If GPA_1 is Low and GPA_2 is Low and knowledge is Low and Participation_in_3D_VLE is Good and amount_of_attenda... | 1 | rule19 |
| 20 | If GPA_1 is Low and GPA_2 is Low and knowledge is Low and Participation_in_3D_VLE is Good and amount_of_attenda... | 1 | rule20 |
| 21 | If GPA_1 is Low and GPA_2 is Low and knowledge is Low and Participation_in_3D_VLE is V_Good and amount_of_atte... | 1 | rule21 |
| 22 | If GPA_1 is Low and GPA_2 is Low and knowledge is Low and Participation_in_3D_VLE is V_Good and amount_of_atte... | 1 | rule22 |

**Figure 8.** A rule-based fuzzy logic system.

## 6. Defuzzification and Experimental Results

The final step in fuzzy logic systems is to convert the fuzzy membership value into a single number or numerical value. This is done using the membership function of the output variables [17,18]. The centroid method is most commonly used for this purpose. The Centroid Method is the defuzzification method with the most appropriate and physically appealing center of gravity. The centroid method in defuzzification has the following Formula (2):

$$\chi* = \frac{\int \mu_{c(x)xdz}}{\mu_{c(x)dz}} \quad (2)$$

where,

$\chi*$ = Defuzzified output
$\int$ = a mathematical integration
$\mu_{c(x)}$ = Aggregated Membership function
$x$ = output variables (1).

Table 7 shows how many points each disabled university student earned on their all exams. Each student's score was fuzzified using a trapezoidal membership function.

**Table 7.** The Disabled Student's Performance Scores.

| Disabled Student | GPA [0–100] | Knowledge [0–100] | Participation in 3D VLE [0–20] | Amount of Attendance [0–100] | 3D VLE Disabled Student Assessment [0–100] | Traditional Disabled Student Assessment [0–100] |
|---|---|---|---|---|---|---|
| 1 | 50 | 50 | 5 | 41.3 | 62.4 | 36.5 |
| 2 | 93 | 10 | 10 | 61.5 | 59.6 | 43.6 |
| 3 | 97.8 | 94.1 | 9.7 | 96 | 91.4 | 96.4 |
| 4 | 89.8 | 89.2 | 7.94 | 96 | 88.3 | 70.7 |
| 5 | 84.3 | 78.7 | 8.74 | 69.5 | 88.5 | 86.6 |
| 6 | 78.1 | 78.7 | 8.19 | 39.8 | 83.3 | 81.2 |
| 7 | 73.8 | 94.1 | 9.6 | 25 | 82.1 | 79.5 |
| 8 | 67 | 80.6 | 8.16 | 26.2 | 72.9 | 67.2 |
| 9 | 28.1 | 76.2 | 5.92 | 26.2 | 62.7 | 57.8 |
| 10 | 49.1 | 55.2 | 7.27 | 84.2 | 55 | 51.2 |
| 11 | 65.1 | 47.2 | 5.92 | 63.2 | 62.3 | 58.4 |
| 12 | 70.1 | 70.7 | 7.94 | 83.8 | 73.6 | 69.5 |
| 13 | 79.3 | 84.3 | 9.23 | 73.8 | 89.3 | 85.9 |
| 14 | 94.8 | 67 | 9.23 | 83.7 | 68.8 | 65.7 |
| 15 | 51.5 | 46 | 5.61 | 29.9 | 62.3 | 59.9 |
| 16 | 66.4 | 67 | 6.04 | 29.9 | 68.7 | 68.7 |
| 17 | 51.5 | 86.7 | 9.11 | 66.3 | 70.5 | 71.4 |
| 18 | 40.4 | 81.8 | 8.44 | 66.3 | 59.8 | 58.5 |
| 19 | 33 | 71.3 | 5.92 | 49 | 62.5 | 61.8 |
| 20 | 92.9 | 89.8 | 8.87 | 94.1 | 91.4 | 89.9 |

Figure 9 presents the surface showing the relationship between the 3D VLE FIS input variables.

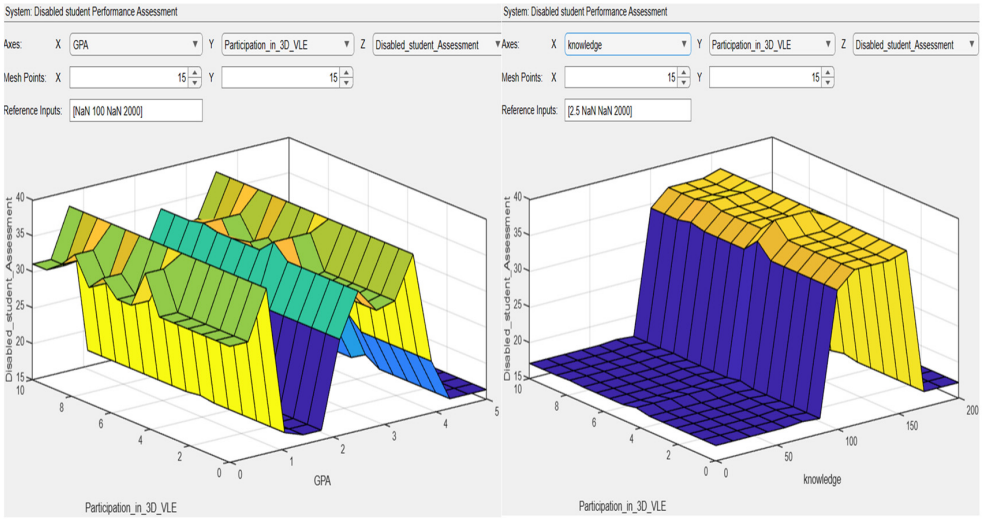


**Figure 9.** 3D VLE FIS input variables surface.

In Figure 10, the MATLAB toolbox was used to calculate the performance of students with disabilities. The Mamdani fuzzy inference system was used to assess the performance of 20 primary and middle school disabled students. The results showed that disabled students generally perform worse on average than non-disabled students, but this difference is not as large as it would be if assessed using conventional methods. The evaluation results in Table 7 show that the 3D VLE FIS that uses fuzzy rules produces a higher score than the 2D VLE FIS that uses 90% of disabled students' assessment results. This means that the 3D VLE FIS is more accurate in identifying students who are disabled.

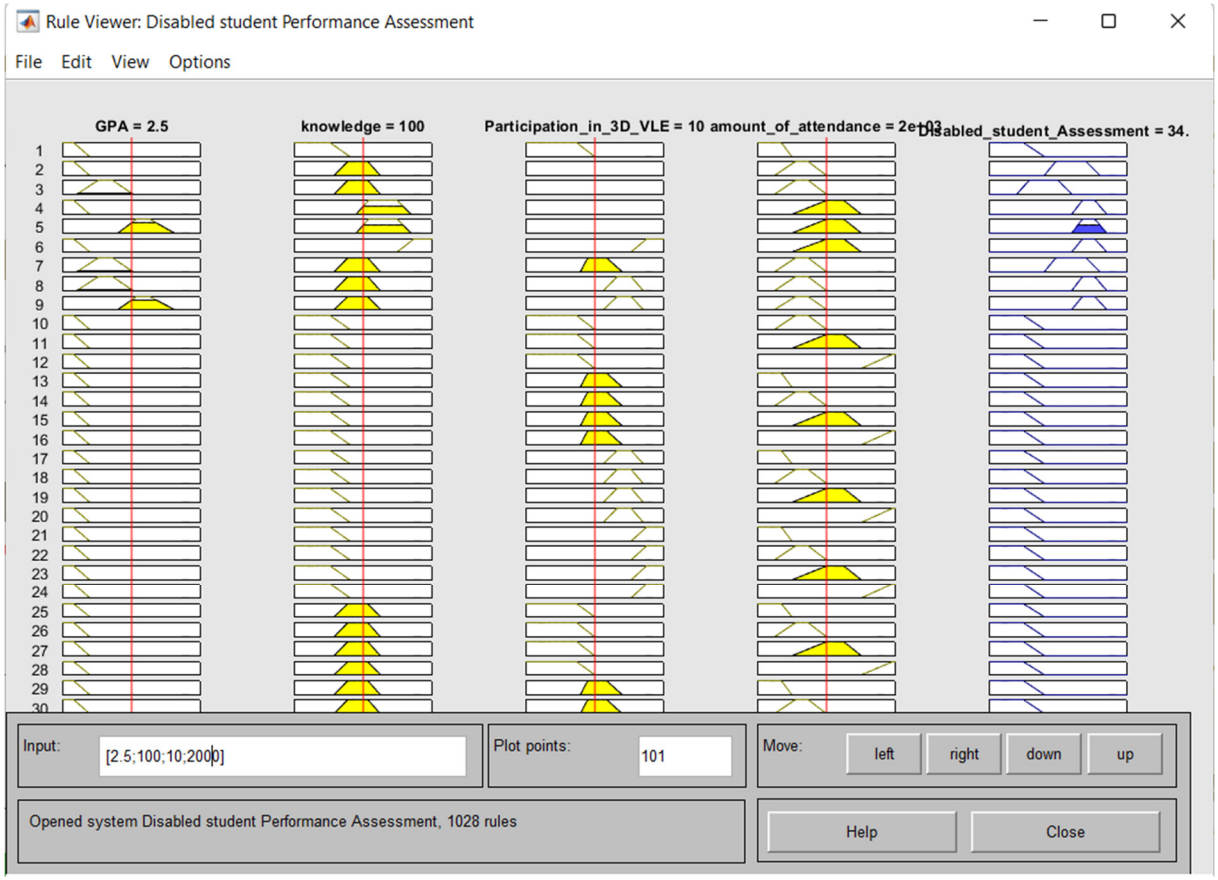


**Figure 10.** The result of Disabled Student Assessment with MATLAB Toolbox.

The study found that fuzzy logic creates a different evaluation from that of traditional assessments of actual worth. The average difference between the fuzzy inference system and conventional evaluations is 3.9 points. Furthermore, to calculate the difference between the fuzzy inference system and conventional evaluations we used a *t*-test which tells us how significant the differences between groups are. This can either be a paired or unpaired *t*-test depending on whether the data is paired or unpaired. The goal is to find the *p*-value and if the *p*-value is less than 0.05 then there is a significant difference between the two groups. If it is more than 0.05 then there is no significant difference between the two groups. The formula for the *t*-test is shown below as Equation (3).

$$t = \frac{\bar{x}_{1-}\bar{x}_{2}}{\sqrt{\left(\frac{(N_1-1)S_{1+}^2+(N_1-1)S_2^2}{N_1+N_2-2}\right)\left(\frac{1}{N_1}+\frac{1}{N_2}\right)}} \quad (3)$$

The study found that since the *t*-test function value is 0.004, which is less than 0.05, we have sufficient evidence to say that the difference between the fuzzy inference system and conventional evaluations is statistically significant.

Figure 11 shows how well the assessment results match up between using classical assessment methods and using a method that uses fuzzy logic. The classical assessment results were based on the average of the four scores from the input variables [27]. Figure 11 also shows that using a 3D virtual learning environment, like the Fuzzy Logic Inference System, can help you get better results than using a traditional assessment.

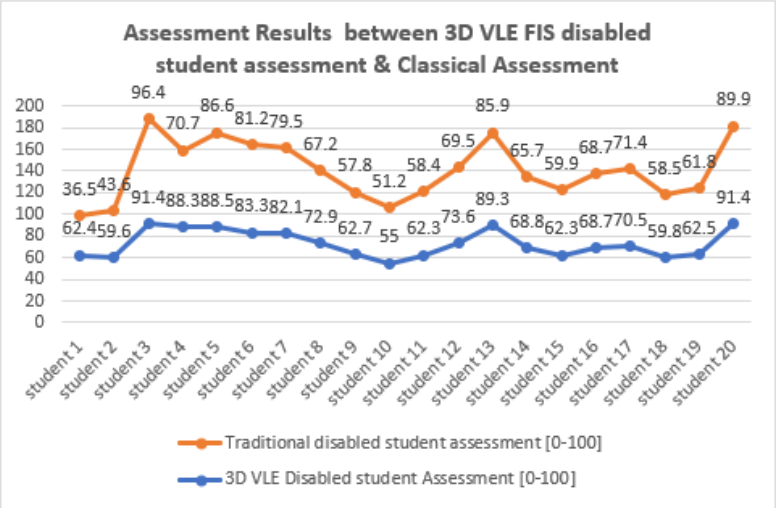


**Figure 11.** Comparison of Assessment Results between 3D VLE FIS & Classical Assessment.

Figure 12 presents how we embed the tools in a 3D object allowing the disabled students to interact with them by touch. This sends an HTTP request to a fuzzy inference system that is programmed using MATLAB and is available as a web app to assess disabled students.

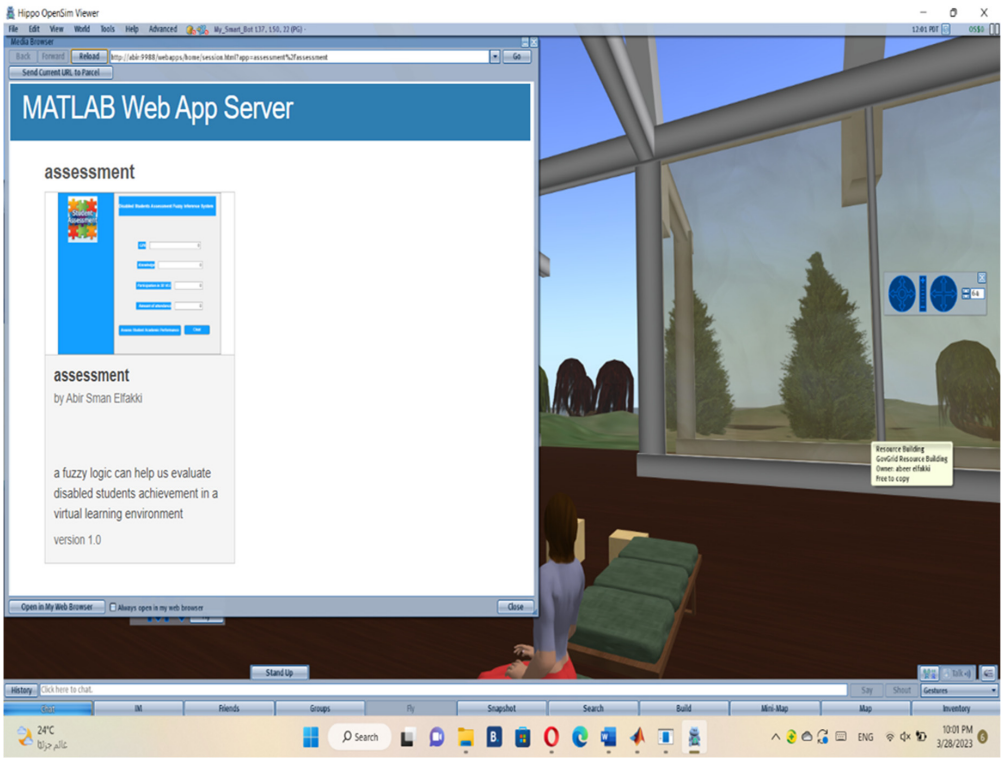


**Figure 12.** Present FIS embedded within the 3D VLE.

*Study Limitation*

This study had some limitations because we were not able to evaluate it with enough students of different ages. We are currently doing a study on middle school students, which means that the participants are aged from 11 to 15 years old. For future research, we will focus on specific disabilities of students in all educational phases. Moreover, to use the fuzzy inference system, we need to input information about knowledge, participation, and attendance as well as experimental conditions. We also need to connect to a learning management system (Moodle) to manage students' activities, tests, and exams. Finally, we need to register disabled students' tasks and assignments, and exams in their Moodle account so that the fuzzy inference system can use them to assess their progress. In the future, we will let the teacher or educational administrator prepare input data about knowledge, participation, and attendance, as well as experiments, and upload it to the disabled student's profile, so that the fuzzy inference system can use it directly. In addition, the use of a 3D virtual learning environment may make it difficult for some students to use. These limitations include learning how to use the system and needing someone to keep an eye on it regularly. The cost of setting up a 3D virtual learning environment can be low if it is based on open-source software, but it is important to have powerful computer hardware to use it properly. To use Moodle in standalone mode, you need to configure it so it can be connected to a 3D virtual environment system and use Sloodle, which is available within Ref. [10].

## 7. Conclusions

The study investigated how fuzzy logic can be used as an intelligent assessment tool for disabled student performance in a 3D virtual learning environment. We use virtual learning tools to help students learn more interactively. We embed the tools in a 3D object, and then disabled students can interact with them by touch. This sends an HTTP request to a fuzzy inference system that is programmed using MATLAB and is available as a web app to assess disabled students. A comparison between the fuzzy inference system and traditional assessment methods had a $p$-value of 0.004, which is less than 0.05, so this means that there is a statistically significant difference between the fuzzy inference system and conventional evaluations. The findings show that fuzzy logic creates a different evaluation outcome from that of a traditional assessment of actual worth. The average difference between the fuzzy inference system and conventional evaluation is 3.9 points. Applying fuzzy set theory to disabled student learning outcomes necessitates more sophisticated tools and techniques, as well as presenting various kinds of evaluations that schools and teachers could use to evaluate students in a 3D virtual learning environment.

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