Metodology for Better Online Learning Efficiency in Blended Learning System By Means of Mamdani Fuzzy Logic

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***Abstract*—There is the specific situation in secondary schools regarding students' understanding of the importance of acquired knowledge which they need for the continuation of their education. Therefore, nowadays it is necessary to introduce innovative forms of knowledge acquiring such as blended learning. The intention is to build an adequate model using Mamdani Fuzzy Logic in terms of better motivation of students with higher and lower metacognitive skills for the online part of teaching. The aim of applied Mamdani Fuzzy Logic method is to determine the best ratio of number of logins on the LMS system, test results and time spent on the LMS system that would give the best results at the final testing. The achieved results show that the applied method effectively determines the best ratio of these three variables in order to achieve the best results at the final testing of different groups of students according to metacognitive skills.**

***Index Terms*—mamdani fuzzy logic, number of logins, test results, time spent on the LMS system, online course efficiency.**

I. Introduction

Secondary education is specific on the issue of mandatory listening of subjects in a classroom and that is why the blended learning model is the only one applicable. The study focused on the online segment of teaching in order to find the best combination of time spent on the Claroline system, number of logins in one day and the results achieved on a test in order to monitor the extent to which students have mastered a teaching unit. Results achieved on the final tests of Informatics also depend on this ratio, fulfilling the condition that all the pedagogical measures for the course creation in terms of content are being carried out.

In order to have the best possible results on the final exam, special emphasis in the research is given to students with higher and lower metacognitive skills because the practice displays a different ratio in terms of these three factors of these two groups of students.

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II. The Research Process

Students of electrical engineering, namely classes I, II, III and IV, participated in this research. Given that there are two sections of each class who are educated for that profession, the research was carried out almost two school years. Only students of Class I had no experience in using the Claroline system.

Fig. 1 displays the classes included in the research over the two school years. It is clear from the Figure that some classes in the control as well as in the experimental group were comprised over the two school years. The number of students comprised in individual classes is also displayed. In the academic 2011/12, Classes IV1 and IV2 were alternately subjected to experimental and control groups so that the IV1 was subjected to experimental group and IV2 to the control group in the first semester, while they reversed in the second semester. This was carried out in order to see whether we have some factors in experimental group that could influence on the test results as the additional aspect of teaching, and which were not examined in the research.

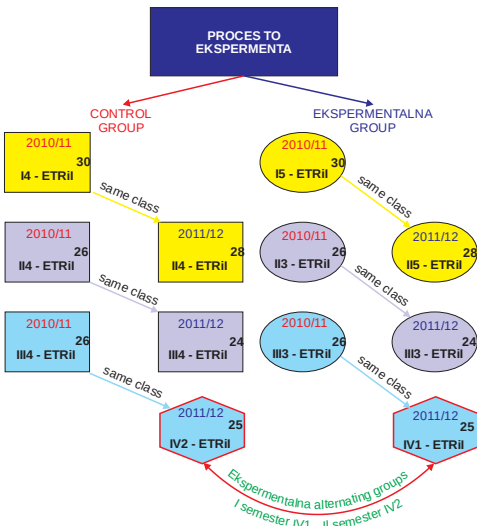

Figure 1. Classes of control and experimental groups

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The control and experimental groups listened the same classical curriculum, therewith the experimental group was exposed to additional form of teaching through e-learning, which they followed from home or Internet clubs. This means that students in the experimental group did not use e-learning platform in school. Both groups had the identical written test at the beginning and at the end of the experiment. The research was carried out by a group scheme with the control group and observation before and after the treatment. The experimental group was exposed to the independent variable (treatment), and the control group was deprived of it.

III. Evaluation of Students Achievement by Mamdani Fuzzy Inference System

Mamdani method represents the new approach to the problems of managing the nonlinear systems. Fuzzy systems are mostly used for modeling decision-making method in the presence of uncertainty. When considering the characteristics of the fuzzy variables and the overall fuzzy system, as well as the results obtained by testing on real numerical data, the chosen approach proved to be adequate. Fuzzy logic does not define one element belonging to a certain set precisely, that belonging is usually measured in percentages. Fuzzy managing provides a formal methodology for representing, manipulating, and implementing a human heuristic knowledge about how to control one particular system.

IV. The Fuzzy Controller Structure

In order to enable practical implementation, the fuzzy concepts are defined: fuzzy set, fuzzy variable, fuzzy term, fuzzy rule and fuzzy value. The components of the fuzzy controller are displayed on the Fig. 2.

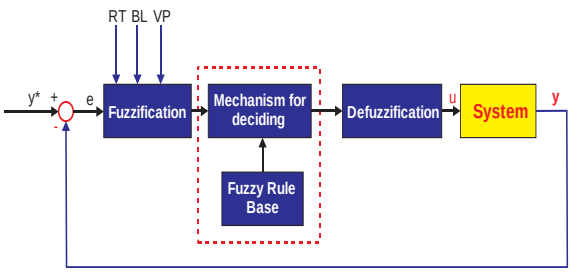

Figure 2. The Fuzzy controller structure [1]

The rule base contains the knowledge about how to control the system in the best way in the form of a logical set (if – then) of rules. Fuzzyfication modifies the input signals so that they can be compared with the rules in the fuzzy rule base. The decision-making mechanism is the mechanism for assessing which control rules are relevant to the current state of the system and it decides with logical set what kind of the control signal it will be, i.e. how it will enter into the process. Defuzzyfication transforms the assessment of the decision-making mechanism into the signal type so that it can be the signal representing the process entering.

According to [2], students' learning efficiency can be improved by giving them more freedom considering the control of the mentioned elements, thus taking the responsibility for their own learning.

However, in our conditions, having the absence of adequate values that students would recognize in terms of achieving the highest possible level of knowledge for their own future, it is very difficult to give the complete control over the curriculum mastering.

Guidelines for the best use of student controlling towards the learning optimization [3]:

- Use student controlling over the content on the LMS platform by students with high level of pre-knowledge or students who have outstanding metacognitive skills for the material intended for gifted students,
- When student controlling is directed to the teaching content in the context of adequate navigation that leads to the important elements of learning materials
- When student controlling is directed to pieces of advice from teachers, with the aim of helping students to effectively master the material needed for achieving the results required in written and oral exams.

With the analysis of the results obtained in the survey conducted among students of the experimental group of the 4th grade of high school, electricians of Computing and Informatics, the analysis of statistical data related to a number of logins during the course length of the subject Programming and computer languages, the time spent on the LMS platform and the results achieved in online tests intended to determine specific teaching units, the aim is to establish which combination of these three factors is the best for the course efficiency.

This class has been taken because of being longer in the LMS function, which the same students use since the first grade. For this reason, they have significant experience considering the system, and thus all the negative influences were eliminated in terms of efficiency of the system usage due to insufficient system understanding.

By monitoring students of this class with the system, especially by teachers in blended teaching of students, i.e. through classical and online teaching, the differences were noted considering the perception of students with higher and lower metacognitive skills towards the content on the LMS platform.

Content controlling by students with lower metacognitive skills is reflected in the fact that they often log in to the system, retain little and are prone to a content with less data, which is reflected in the usage of multimedia materials that essentially contains less pieces of information and which are insufficient to give the basic level of knowledge required for this age group of students. Students with higher metacognitive skills have smaller number of logins on the LMS system, but they retain longer. Content control by these students is continuous and systematic.

V. Proposed Problem Solution

MATLAB R2009b was used for conducting the research. Based on the survey results and statistics reported by Claroline LMS system, there are the data classified for two groups of students, namely students with high metacognitive skills and students with lower metacognitive skills.

A choice of controller input and output represents the first step in designing, shown in Table I. Variables that carry information about the system behavior should be the controller inputs.

Fuzzy regulator is Mamdani controller, the accumulation of activated conclusions using max operator. There are four defined linguistic input variables: RT variables have discrete values in the range [1], [5], BL discrete values in the range [0, 10], VP discrete values in the range [0, 3], and the ELMS output variable can receive values from the range of [0, 1].

TABLE I. LIST OF USED VARIABLES IN THE FUZZY SYSTEM

Linguistic variables	Variable type	Linguisticterms
RT – online tests results for teaching units determining	Input	RS –weak RD - good RO –excellent
BL – number of logins during the course length–average	Input	BM – small BS – middle BV – high
VP – average time spent on the LMS platform	Input	VM – small VS – medium VP – high
ELMS – e-learning efficiency	Output	ESK – modest ESR – middle EDO –good

The next step is the selection of the control variable, or the process input. To make the controller able to make decision on the value of the control variable, it must receive enough information through the input signals. Also, the controller must have an output which will manage the system so as to bring it to the required state with desired performances.

All of this is defined in the Fig. 3 FIS editor, which defines the basic input and output signals, and their features and values that can receive individual variables.

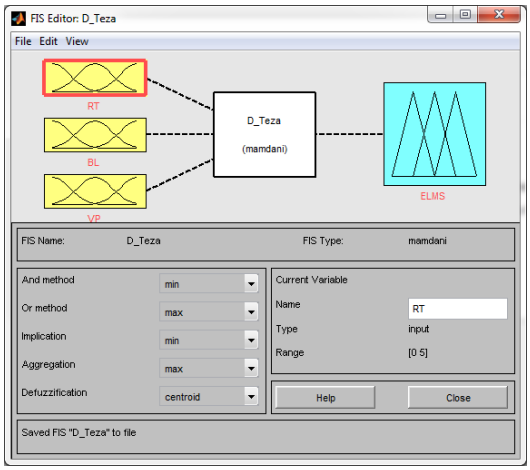

Figure 3. FIS editor

RT variable – online test results for knowledge self-check of a particular teaching unit can receive values in the range of [0, 5]. In order to describe the results, we took Gaussian value distribution curve and we divided it into linguistic conditions of poor, good and excellent results which can be achieved by students, and which is shown in Fig. 4.

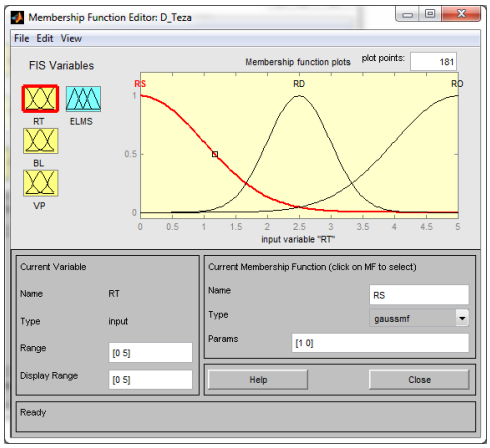

Figure 4. Membership function editor for RT variable

At BL variable – number of students' logins on the LMS system, Gaussian results distribution curve is also applied. There are linguistic conditions of small, medium and large number of students' logins in one semester, and where the average value is taken.

VP variable – time spent on the LMS platform per one login, the average value was taken for each student who was included in the experimental group of students. In order to describe the results, we took Gaussian value distribution curve and we divided it into linguistic conditions of small, average and high amount of time spent on content control per one login on the system.

ELMS variable – e-learning efficiency, which is reflected on the achievement of online tests that were done after each processed field toward curriculum for the subject Programming and programming languages. This is the output variable which has been divided into linguistic conditions of modest, medium and good efficiency of e-learning influence on the results achieved by students. The membership function overview is given in Fig. 5.

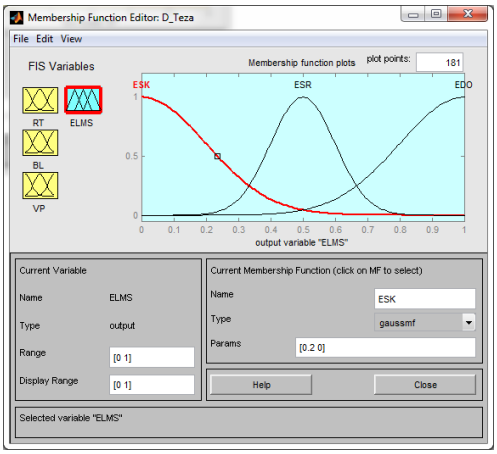

Figure 5. Membership function editor for ELMS variable

The aim of the fuzzy controller is to map the mapping of controller inputs into outputs using the fuzzy logic. The primary mechanism for that is a list of if-then theorems which we call rules [4]. All rules are being executed parallel and their sequence is not important. The rules are related to linguistic variables and their features. The rules are defined in the Editor.

The rules are:

- If (RT is RS) and (BL is BM) and (VP is VM) then (ELMS is ESK) (1)
- **If** (RT is RS) and (BL is BS) and (VP is VM) then (ELMS is ESK) (1)
- If (RT is RS) and (BL is BV) and (VP is VM) then (ELMS is ESK) (1)
- If (RT is RD) and (BL is BM) and (VP is VS) then (ELMS is ESR) (1)
- If (RT is RD) and (BL is BS) and (VP is VS) then (ELMS is ESR) (1)
- If (RT is RD) and (BL is BS) and (VP is VP) then (ELMS is ESR) (1)
- If (RT is RO) and (BL is BM) and (VP is VS) then (ELMS is EDO) (1)
- If (RT is RO) and (BL is BS) and (VP is VS) then (ELMS is EDO) (1)
- If (RT is RO) and (BL is BS) and (VP is VP) then (ELMS is EDO) (1)

From the rule base, it can be seen that the conjunction was used in determining the rules.

Substantially, the defuzzyfication is opposite to the fuzzyfication process, so it is called decoding [5]. In fact, this is a process that needs to convert the aggregation result, which basically represents a cut of section area into the signal which is conceivable to the process. Controller output must have a unique value, usually represented with a real number.

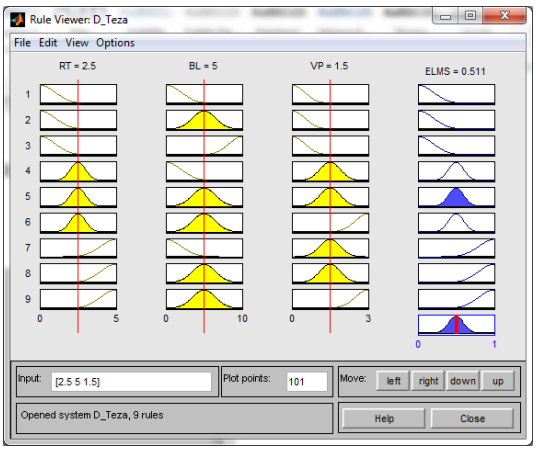

Figure 6. Rule viewer for students with lower metacognitive skills

Setting the initial fuzzy system may be described in the following example. For the first group of users, i.e. for students with lower metacognitive skills, the best solution is the one using variables as follows: RT when having a value between 2.4 to 3.1, BL when having a value from 4 to 6 and VP when it receives a value between 1.4 and 1.7. The result obtained by the modified fuzzy system, having the gravity center as the defuzzyfication method, amounts 0.511 which in its fullest extent belongs to a fuzzy set of "medium" efficiency degree. This means that students of this category need to spend medium time on the LMS platform, use medium number of logins and have good test results for checking scientific teaching units. To achieve this, they must have help from teachers, through the classic form of education in traditional education process as well as through the work in the Claroline system. Everything is given in Fig. 6.

For the second group of users, i.e. for students with higher metacognitive skills, the best solution is the one using variables as follows: RT when having values between 4 and 5, BL when having a value from 4 to 5 and VP when receiving values between 2.5 to 3.The result obtained by the modified fuzzy system, with the gravity center as the defuzzyfication method, amounts 0.844which in its fullest extent belongs to a fuzzy set of "high" intensity of e-learning efficiency. This means that students of this category need to spend more time on the LMS platform, have medium logins and have excellent test results for checking scientific teaching units. To achieve this, they must have a content that is adequate and interesting for gifted students, and with the possibility of practical experiments, i.e. applications for the use in practice. Everything is given in Fig. 7.

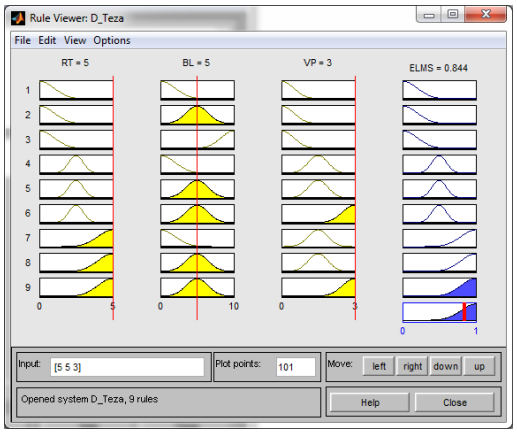

Figure 7. Rule viewer for students with higher metacognitive skills

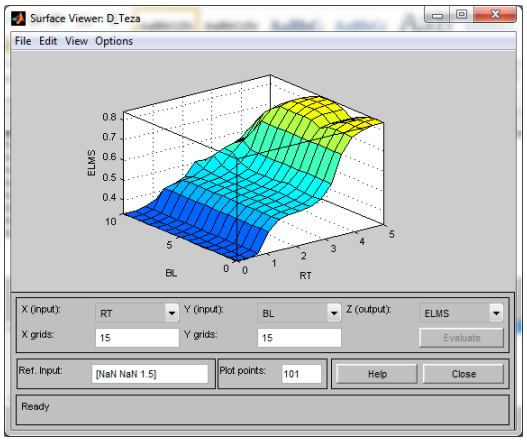

Figure 8. Three-dimensional transfer functions of the fuzzy system

When all the methods which will be applied are determined: methods of fuzzyfication, operator, implications, defuzzyfication – it is possible to get a

three-dimensional transfer surface for every combination of two input variables is shown in Fig. 8. This surface illustrates the output behavior depending on the input variable combination.

Based on the results obtained in this research, all the advantages of fuzzy logic appliance by using fuzzy system are visible. The research in the field of online teaching reveals the possibility of using the methodology based on the fuzzy inductive logic.

Fuzzy implication has the property of consistency and completeness. This supervenes from the fact that neither rule conclusion has a conflict with the conclusion of another rule. As already mentioned, the rules are parallel and their sequence has no influence.

VI. Conclusion

Based on the results obtained in this research, all the advantages of fuzzy logic appliance by using the fuzzy system are visible. The research in the field of online teaching reveals the possibility of using the methodology based on the fuzzy inductive logic. This is the most universal model for the best combination of input variables given by the research, in order to obtain the best results in the online environment for all categories of students. In further research, it is also possible to introduce the kind of content as an additional input factor in the controller.

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