APPLICATION OF ARTIFICIAL INTELLIGENCE METHODS FOR ANALYSIS OF TEACHING EFFICIENCY

Marija Mojsilović[1] Đorđe Mihailović[2] Snežana Gavrilović[3] Veljko Spasojević[4]

Abstract: The effectiveness of teaching is one of the key indicators of the quality of the educational process and directly affects academic success and the level of acquired knowledge. The goal of this paper is the application of the artificial intelligence method, specifically the adaptive neuro-fuzzy inference system (ANFIS), for the analysis of factors that influence the effectiveness of teaching. The six most important factors were singled out as input variables: comprehensibility and clarity of presentation, applicability of knowledge in practice, quality of teaching material, teacher's commitment, working atmosphere in class and objectivity of assessment. The output variable is defined as the level of knowledge or grade achieved. The model enables the analysis of complex relationships between input factors and output value, as well as the prediction of teaching effectiveness based on combined pedagogical and motivational indicators. The obtained results show that ANFIS is an effective tool for assessing and improving the quality of education, as it enables the identification of factors with the greatest impact on achievements and provides a basis for further improvements in the teaching process.

Key words: Artificial intelligence, ANFIS, Analysis of teaching effectiveness, Educational process, Prediction of knowledge

1. INTRODUCTION

Education plays a key role in the personal and professional development of an individual, and its main purpose is to facilitate the acquisition of knowledge and skills necessary for a successful life and professional career. Mastering the curriculum and achieving academic goals is a fundamental part of the educational process. However, achieving these goals is often challenging, as various factors can affect how effectively an individual acquires and applies new knowledge [1].

The effectiveness of teaching is one of the key indicators of the quality of the educational process, because it directly affects the level of acquired knowledge and the academic achievements of the participants. Understanding the factors that contribute to successful learning allows teachers and institutions to improve educational methods and optimize the teaching process. Traditional teaching evaluation methods often rely on subjective assessments and statistical analyzes that cannot fully capture the complex and non-linear relationships between various pedagogical, motivational and organizational factors [2].

In modern education, the application of artificial intelligence methods provides new opportunities for detailed analysis and prediction of teaching effectiveness. Particularly useful are intelligent models that combine the principles of neural networks and fuzzy logic, such as the adaptive neuro-fuzzy inference system (ANFIS), because they enable modeling of complex and uncertain patterns in data [3][4].

Through the analysis of relevant studies and works, the research focuses on the identification of key factors that influence the effectiveness of teaching [5]. These factors, including the clarity of presentation, the applicability of knowledge in practice, the quality of teaching materials, the commitment of teachers, the working atmosphere and the objectivity of assessment, represent input variables that significantly determine the level of achieved knowledge [6]. A literature review provides a basis for understanding the interplay of these factors and how they can be optimized to achieve better educational outcomes [7]-[9].

The application of artificial intelligence in education, especially adaptive neuro-fuzzy systems (ANFIS), enables the modeling of complex and non-linear relationships between input factors and

[1]dr Marija Mojsilović, Academy of Professional Studies Sumadija, College in Trstenik, mmojsilovic@asss.edu.rs
[2]dr Đorđe Mihailović, Academy of Professional Studies Sumadija, College in Aranđelovac, djmihailovic@asss.edu.rs
[3]dr Snežana Gavrilović, Academy of Professional Studies Sumadija, College in Trstenik, sgavrilovic@asss.edu.rs
[4]msc Veljko Spasojević, Academy of Professional Studies Sumadija, College in Trstenik, vspasojevic@asss.edu.rs

academic success [10][11]. These models provide the potential for precise analysis and prediction of teaching effectiveness, making it easier for teachers to identify key areas for improving teaching and improving student outcomes. Artificial intelligence, through its capabilities in data processing and adaptive learning, is a powerful tool for supporting education and optimizing the process of acquiring knowledge.

The aim of this paper is the application of the ANFIS method for the analysis of key factors that influence the effectiveness of teaching. Factors that have the greatest impact on the quality of the educational process were taken as input variables: comprehensibility and clarity of presentation, applicability of knowledge in practice, quality of teaching material, teacher's commitment, working atmosphere in class and objectivity of assessment. The output variable is defined as the level of knowledge, i.e. the grade achieved, which enables the quantification of teaching effectiveness and the application of models for prediction and improvement of the educational process.

2. THEORETICAL SETTINGS OF THE RESEARCH

Software based on the principles of soft computing, in contrast to the traditional approach to computer problem solving, relies on the use of approximate models and enables finding solutions to complex real-world problems [12]. The application of soft computing involves combining artificial intelligence tools, such as neural networks and fuzzy technologies, into a unique hybrid system for solving practical problems [13]. Training the ANFIS model involves determining the parameters using optimization methods. The first ANFIS model, developed by Young, applies a hybrid learning approach to system training [14]. Adaptive neuro-fuzzy inference system (ANFIS) represents one of the most widespread hybrid neuro-fuzzy systems [15]. Through the application of neural networks, it is possible to construct a fuzzy inference model that enables the estimation of the parameters of membership functions based on the available input-output data. Within the ANFIS algorithm, the data passes through four layers of the network, where the least squares method is used to precisely determine the required parameters.

In this paper, the bell membership function was used, because it enables efficient modeling of non-linear data. A bell-shaped membership function can be defined as follows:

$$\mu(x) = bell(x; a_i, b_i, c_i) = \frac{1}{1+\left[\left(\frac{x-c_i}{a_i}\right)^2\right]^{b_i}} \quad (1)$$

Where is:

x – input size; a_i, b_i, c_i – given parameters.

The rule base of the ANFIS structure consists of phased IF-THEN rules. A system with two inputs and one output is used to describe these rules:

The rule 1: IF ((x is A1) and (y is B1)) THEN (z is f1)

The rule 2: IF ((x is A2) and (y is B2)) THEN (z is f2)

Where is:

x , y - input size,

z – output size,

Ai , Bi (i=1,2) –fuzzy sets (linguistic variables)

f i (i=1,2) – exits the inference system.

The possibility of forming a model of the fuzzy inference system using neural networks is used to calculate the parameters of the membership function based on the available input-output data. The model is defined based on the available knowledge about the process under consideration. In the first pass through the ANFIS network algorithm, the signals go forward all the way to the fourth layer,

where, using the least squares method, the consequent parameters are determined. In the backward pass, the error rates are propagated backwards and the premise parameters are updated by gradient descent. Training and testing of the ANFIS network was done in the Matlab software package. According to the collected input-output data pairs based on experimental tests, a given ANFIS network could determine the most influential parameters for a certain output parameter over the prediction error. In this paper, the least squares error, which can be represented by the equation, is used as the basic criterion to establish the accuracy of the prediction.

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(P_i - Q_i)^2}{n}} \quad (2)$$

Where is:

P_i and Q_i – experimental and calculated data,

n – total number of data.

3. METHODOLOGY AND DATA

The subject of research in this paper is the analysis of the influence of various factors on the effectiveness of teaching. The goal is to identify the key factors that have the most significant impact on the achieved level of knowledge and explore the ways in which the application of artificial intelligence methods, specifically the ANFIS system, can contribute to the optimization of the teaching process in order to achieve better teaching efficiency.

This research paper aims to examine the influence of various input factors - such as clarity of presentation, applicability of knowledge in practice, quality of teaching material, teacher's commitment, working atmosphere in the class and objectivity of assessment - on the achieved level of knowledge. In order to achieve an optimal model and improve the effectiveness of teaching, which is the main goal of this research, it is necessary to take into account the factors that have the greatest influence on the educational process. A variety of factors can significantly affect teaching effectiveness, as shown in Table 1. Some of these factors include:

- Comprehensibility and clarity of presentation - This factor refers to the teacher's ability to present the material in a clear, logical and accessible way. Clearly structured teaching allows students to more easily follow the material, understand concepts and connect theory with practice. If the presentation is unclear or confusing, the achieved level of knowledge can be significantly reduced.
- Applicability of knowledge in practice - evaluates how well learned material can be directly applied in practical situations or professional environment. Subjects and examples that have practical value motivate participants to actively learn and remember the material better, which directly affects the effectiveness of teaching.
- Quality of teaching materials - This includes the availability and relevance of teaching resources, including books, presentations, exercises, laboratory assignments and other materials. Quality materials facilitate the learning process and enable independent repetition and deepening of knowledge.
- Teacher's commitment - refers to the teacher's engagement and motivation during classes, as well as his willingness to provide additional support to the participants. A dedicated teacher better monitors progress, provides feedback, and adapts instruction to student needs, which increases learning effectiveness.
- Working atmosphere in the class - Includes mutual interaction between teachers and participants, a stimulating and pleasant working climate, as well as the level of student engagement. The pleasant atmosphere and active participation of participants motivates learning and enables a better exchange of knowledge and experiences.
- Objectivity of assessment - it should be fair, transparent and based on clearly defined criteria. When the participants perceive the assessment as objective, the motivation for learning and effort is greater, which directly affects the level of knowledge achieved and the effectiveness of teaching.

Research related to the analysis of factors that influence the effectiveness of teaching was conducted at the Academy of Vocational Studies in Šumadija - Trstenik Department. The data were collected during two school years on courses in the field of information technology, in the first year of professional studies, and included 177 respondents. The information was collected through a combination of official statistical data of the school and a survey conducted among the participants, where a Likert scale was used to evaluate the factors that influence the level of knowledge achieved. The goal is to identify the key factors that have the greatest impact on teaching effectiveness.

Table 1 – Input and output parameters

Input and output	The name of the input parameters	Range
Input 1	Comprehensibility and clarity of presentation	0 - 10
Input 2	Applicability of knowledge in practice	0 - 10
Input 3	Quality of teaching material	0 - 10
Input 4	Teacher commitment	0 - 10
Input 5	Working atmosphere in class	0 - 10
Input 6	Objectivity of assessment	0 - 10
Output	Grade/Knowledge	5-10

4. RESULTS AND DISCUSSION

Table 2 shows the results of applying the ANFIS method, including the average error value, average deviation, root mean square error, and root mean square error for the training and testing datasets. Table 3 also shows the reliability coefficient of the obtained model for the input factor that has the greatest influence on the output size. In this research, the RMSE value was used to compare the accuracy of the model during the training and testing process. The obtained values show that the model achieves satisfactory precision, which confirms that the identified input factors, especially the commitment of the teacher, have a significant and measurable impact on the effectiveness of teaching.

Table 2 – The impact of one input on the output

INPUT 4
TRAINING – ERROR SV = 0.000000 SD = 0.356083 MSE= 0.125354 RMSE= 0.354054
TEST – ERROR SV = 0.267481 SD = 0.458234 MSE= 0.268401 RMSE= 0.518074
ALL DATA – ERROR SV = 0.041151 SD = 0.38351 MSE= 0. 14736 RMSE= 0.38388

The linear correlation coefficient is a measure of the degree of association between the actual output values and those generated by the model during training and testing. The value of the R coefficient ranges from 0 to 1, with higher values indicating higher reliability of the model. It is considered that the model is sufficiently reliable if the coefficient of linear correlation is greater than 0.8. This analysis enables the assessment of the accuracy and stability of the model, which is of key importance for confirming the set research hypotheses.

Table 3 – Reliability of the model

Reliability of the model
TRAINING – ERROR R = 0.99434
TEST – ERROR R = 0.99722
ALL DATA – ERROR R = 0.99323

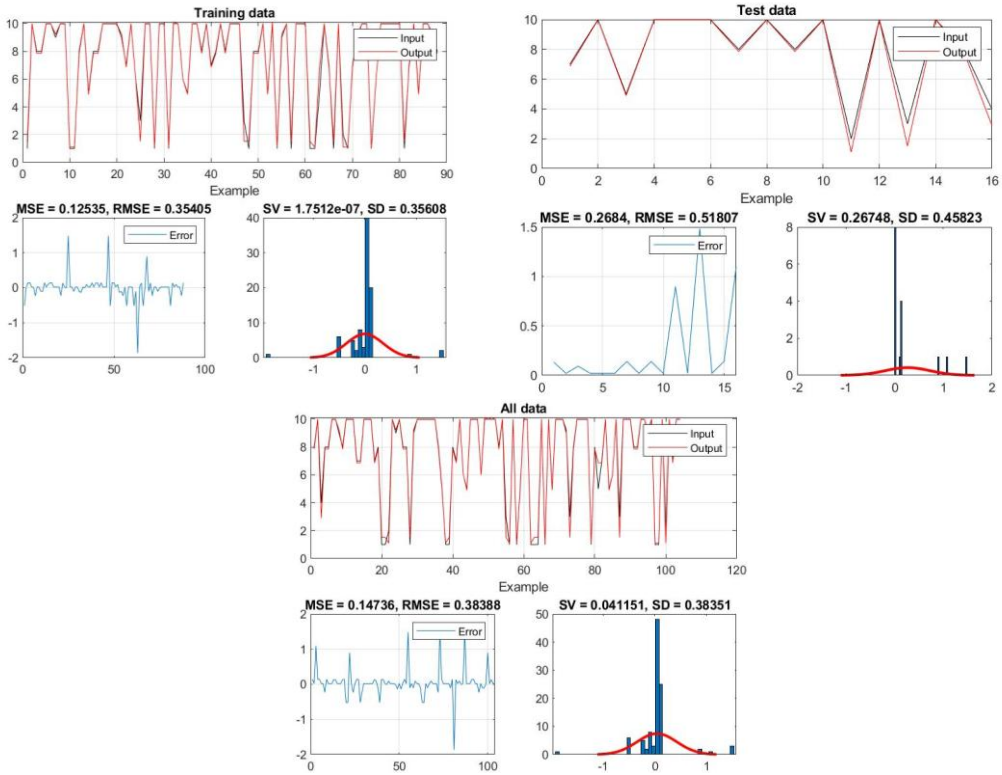

Figure 1 – ANFIS network training, test and all data

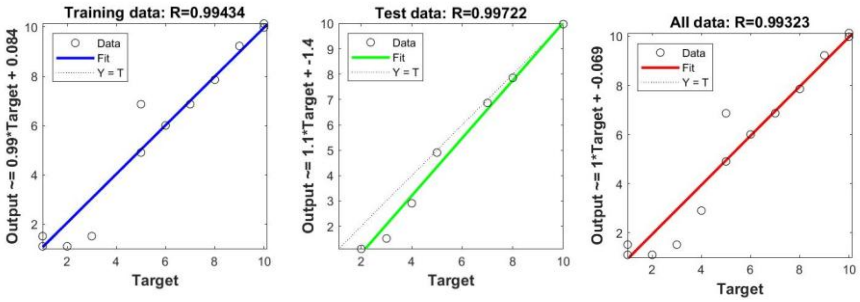

Figure 2 – Regression of training, test and all data

Figure 1 shows data on errors during the training and testing process and for the entire data set obtained by applying the ANFIS methodology in the Matlab software environment. Figure 2 illustrates the regression analysis and reliability of the model, while Figure 3 presents a graphical interpretation of the data used for training.

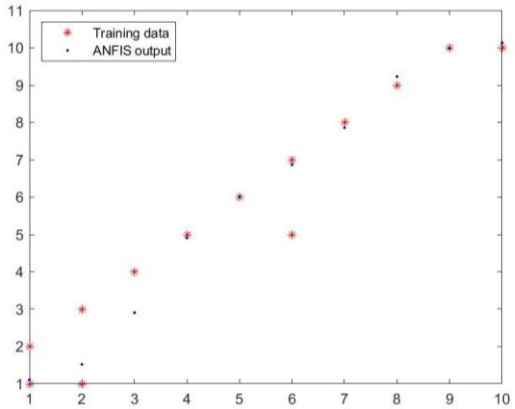

Figure 3 – Graphical interpretation of training data

5. CONCLUSION

The purpose of the conducted research was to analyze the influence of various factors on the effectiveness of teaching using the ANFIS methodology. Defined input factors - comprehensibility of presentation, applicability of knowledge in practice, quality of teaching material, dedication of teachers, working atmosphere and objectivity of assessment - represent key elements of the educational process that affect the level of knowledge achieved. The results of the model showed that all the mentioned factors have a certain influence, but that the teacher's commitment plays the biggest role in improving the effectiveness of teaching.

The obtained values of RMSE and coefficient of determination (R) confirm the reliability and precision of the developed model, which indicates that the ANFIS method can be successfully applied in educational research to assess and predict the effectiveness of teaching. This confirms that the application of artificial intelligence methods provides a significant contribution to the understanding of the complex relationships between the factors that shape the educational process and the achieved results.

Further research can be aimed at expanding the set of input variables, applying it to different teaching areas, as well as comparing the ANFIS method with other soft computing and artificial intelligence algorithms, which would further improve the accuracy and practical applicability of the obtained results.

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