Some Approaches to Analysis of Learning Trajectory Correction Using Theory of Fuzzy Sets

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Abstract - Modern society is characterized by a high development of technology, which forces a person to timely retrain in a professional way. The educational process requires new educational technologies. The user of educational technologies needs approaches to assess his level of knowledge. Such approaches for evaluation can be developed using a fuzzy set apparatus.

Keywords - educational technologies; linguistic variable; learning process; consumer

I. INTRODUCTION

World society is associated with the rapid development of technology, the change of nature, the emergence of new forms of employment and interaction of people, which in turn requires knowledge connected not only with one’s professional field of activity, but also with knowledge of related work areas. To take up a successful position in society, a person needs to be well-oriented in the information space, be able to master the skills in time, have communication skills, and think creatively, which often requires the necessary education.

Modern education is characterized by a dynamically increasing and changing amount of knowledge in various branches of science and industry. Mastering a large amount of information in the learning process is problematic when using only classical learning technologies that are limited by time, geography and territory. Consequently, in such situations it is necessary to develop and use the latest educational technologies, combining both traditional methods, information and communication.

Information and communication educational technologies imply the totality of educational technologies using various possibilities of information technologies (author's educational disciplines, electronic library fund, multimedia, online technologies, etc.). The purpose of the development of new educational technologies is to improve the quality and speed of perception of educational material, to improve the quality of educational content, to develop approaches to adjust educational trajectories, which will allow the consumer of educational services to improve the educational level.

Modeling new educational technologies implies a combination of both developed knowledge structures and the presentation of educational material in different forms (choosing the form of presentation of educational material, colors when working with educational material, accompaniment/deactivation of sound, availability of graphic material, availability of a testing unit, tips, monitoring learning outcomes), as well as providing the consumer with educational services, the opportunity to monitor and analyze learning outcomes. All this will allow the consumer of educational services to carry out the learning process more effectively, and, if necessary, to make adjustments to the learning process, using various educational technologies available in the educational process of the educational institution.

II. CHARACTERISTICS OF THE STUDY AREA.

The educational process in a higher educational institution consists of a combination of various types of training (full-time education, distance learning, distance learning, advanced training), various training technologies that accompany relevant forms of education, subject to management control. In the global approach, a fragment of the structure of the educational process of a higher educational institution can be shown as in Fig.1. In the presented scheme, the consumer of educational services is an active participant in the educational process.

![Fig. 1. Components of the structure of the educational process of a higher educational institution.](image)

Based on the above, it can be concluded that the learning process is a complex semi-structured system consisting of a set of indicators that are different in nature [1-4]. The system
is dynamically changing, for formalization of which existing formalized methods and approaches are not always suitable. A system requires adjustments in terms of changing the components that make it up in accordance with requests from the external environment. A system includes a consumer of educational services. A system uses a large amount of different data, for which fuzzy logic will provide an adequate display of uncertainties and inaccuracies.

The continuous development of society is accompanied by the disappearance of existing jobs and the emergence of new jobs requiring training. The task of the higher education institution is to respond flexibly to changes by modifying the corresponding components of the learning process and giving them to the consumer of educational services.

The consumer of educational services as an active participant in the educational process, regardless of the form of education using different training technologies, has the goal of obtaining quality education, which will allow the consumer to improve his position in the labor market and increase the level of demand. The availability of a timely opportunity to adjust the trajectory of training enables the consumer of educational services to obtain the required education and timely respond to the demands of the labor market. To achieve this goal, the consumer of educational services must have the technology to adjust the individual educational route, taking into account the choice of optimal forms and rates of education. There must be the possibility of applying different approaches in training that are most suitable for the individual characteristics of the consumer of educational services. Let us suppose that a consumer of educational services knows that his understanding of the material is more successful if the material he studies not only can be read, repeated as necessary, the most significant moments of the material, but he also has the opportunity to list, use the graphical presentation, discuss the material, etc.

The consumer must have information about the characteristics of the educational process. Fig. 2 presents the structure of the constituent components included in the learning trajectory, with which, if necessary, you can make the required adjustment. In the process of adjusting the learning trajectory, the user inevitably faces the problem of the lack of an unequivocal list of requirements by the level of training, as well as a list of the indicators that should be included in the list being formed, how to evaluate these indicators different in nature [3-9].

The consumer has information about the characteristics of the educational process. Let us suppose that a consumer of educational services received a “good level of knowledge,” but there is no information about vacant jobs in the labor market, or the consumer does not have a sufficiently high level of personal qualities, such as responsibility, etc., to match the vacant job.

III. MAIN PART.

The assessment of such linguistic concepts requires the involvement of experts, which in turn introduces a share of subjectivity. Considering the concept of “level of demand” as a linguistic variable, one should use the apparatus of fuzzy sets in order to adequately describe, formalize and obtain a numerical estimate in the numerical continuum. Imagine the "level of demand" as a set of three components (Fig. 3).

As mentioned above, the availability of the possibility of adjusting the educational trajectory allows the user to strengthen his position in the labor market, i.e. increase their own level of demand in the labor market. It is difficult to
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In this paper we will focus on the development of approaches to assess the level of knowledge. We will define the linguistic variable YZ “level of knowledge” by the following tuple:

\[ YZ = \langle \beta, T, X, G, M \rangle \]

where \( \beta \) – name of the linguistic variable “level of knowledge”;

\( T \) (term set) - contains a set of linguistic values of a variable.

For example, \( T1 \) - "low level of knowledge";

\( T2 \) - “medium level of knowledge”;

\( T3 \) - "a high level of knowledge."

\( X \) is a base set. In this case, the numerical scale [0…100] will serve as the base set.

\( G \) is a syntactic procedure that generates new verbal values of a linguistic variable with the help of modifiers, based on the values included in the term set. For example, “very low level of knowledge” or “more or less acceptable level of knowledge”.

\( M \) is a semantic procedure that forms a set of semantic rules, as a result of which the value of a linguistic variable is mapped to fuzzy sets. The procedure allows one to formalize the qualitative knowledge of experts, which are often presented in the verbal form.

In order to move from a qualitative presentation to a formalized one, it is necessary to develop membership functions. There are no restrictions on the representation of the membership function, but in practice, the most frequently used membership functions are those with a simple mathematical representation.

On the basis of an expert survey procedure, piecewise-linear membership functions, in particular, both triangular and trapezoidal can be used to obtain an estimate of the values “low level of knowledge”, “medium level of knowledge”, and “high level of knowledge”.

Let us define a fuzzy model for the linguistic variable YZ, as a system with three inputs and one output.

\[ X_1 \]
\[ X_2 \]
\[ X_3 \]
\[ y_1 \]

Fig. 4. The structure of a fuzzy model

where \( x_1 \) - results of tests of current performance; \( x_2 \) - the resulting tests; \( x_3 \) - control of independent tasks; \( y_1 \) is the value of output linguistic variable YZ.

The value of the output variable \( y_1 \) is obtained using a simplified fuzzy inference, which includes the following steps:

- development of a base of fuzzy rules;
- fuzzification of input and output variables;
- aggregation of sub-conditions;
- activation of sub-conclusions;
- accumulation of conclusions.

The bases of fuzzy rules are developed on the basis of rules of the form “if ... - then ...” reflecting the expert's knowledge. The peculiarity of such statements is that their adequacy does not change with minor changes in the data. The work presents a fuzzy system, which is based on expert knowledge and developed fuzzy rules. In this case, the fuzzy rules are set when the fuzzy terms membership form is selected, with the help of which the inputs and outputs of the fuzzy system are evaluated. As a rule, the higher the professional level of the expert, the higher the adequacy of the fuzzy model constructed at this stage of setting.

Let us consider the steps of a simplified fuzzy inference in the following view:

- define the input and output linguistic variables and their limits;
- define the membership functions for each input and output variable;
- develop a base of fuzzy rules that will be responsible for
managing operations;
• make the transition from fuzziness to specific numeric values.

Let us imagine each stage in turn.

Definition and interpretation of input variables and their limits. Previously, three parameters were indicated for assessing the level of knowledge; now we use them as three input variables: 
- x1 - the results of tests of current performance;
- x2 - the results of tests;
- x3 - control of independent tasks.
Each input variable will be evaluated on a universal scale [0...100].

TABLE 1 \ CHARACTERISTICS OF THE CURRENT PERFORMANCE TEST SCORES
<table>
<thead>
<tr>
<th>Linguistic characteristic</th>
<th>Lower value</th>
<th>Upper value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excellent result</td>
<td>85</td>
<td>100</td>
</tr>
<tr>
<td>Good result</td>
<td>60</td>
<td>90</td>
</tr>
<tr>
<td>Average result</td>
<td>45</td>
<td>70</td>
</tr>
<tr>
<td>Below the average</td>
<td>25</td>
<td>50</td>
</tr>
<tr>
<td>Bad result</td>
<td>0</td>
<td>35</td>
</tr>
</tbody>
</table>

TABLE 2 \ CHARACTERISTICS FOR THE RESULTING TESTS
<table>
<thead>
<tr>
<th>Linguistic characteristic</th>
<th>Lower value</th>
<th>Upper value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excellent result</td>
<td>85</td>
<td>100</td>
</tr>
<tr>
<td>Good result</td>
<td>60</td>
<td>90</td>
</tr>
<tr>
<td>Average result</td>
<td>45</td>
<td>70</td>
</tr>
<tr>
<td>Below the average</td>
<td>25</td>
<td>50</td>
</tr>
<tr>
<td>Bad result</td>
<td>0</td>
<td>35</td>
</tr>
</tbody>
</table>

TABLE 3 \ CHARACTERISTICS FOR THE CONTROL OF INDEPENDENT TASKS
<table>
<thead>
<tr>
<th>Linguistic characteristic</th>
<th>Lower value</th>
<th>Upper value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excellent performance</td>
<td>85</td>
<td>100</td>
</tr>
<tr>
<td>Very good performance</td>
<td>60</td>
<td>90</td>
</tr>
<tr>
<td>Good performance</td>
<td>45</td>
<td>70</td>
</tr>
<tr>
<td>Not very good performance</td>
<td>25</td>
<td>50</td>
</tr>
<tr>
<td>Poor performance</td>
<td>0</td>
<td>35</td>
</tr>
</tbody>
</table>

Definition and interpretation of output variables and their limits. One output variable is available: y1 - the value of the output linguistic variable \( YZ \). The output variable will also be evaluated on a universal scale.

TABLE 4 \ CHARACTERISTICS OF KNOWLEDGE
<table>
<thead>
<tr>
<th>Linguistic characteristic</th>
<th>Lower value</th>
<th>Upper value</th>
</tr>
</thead>
<tbody>
<tr>
<td>High level</td>
<td>85</td>
<td>100</td>
</tr>
<tr>
<td>Good level</td>
<td>60</td>
<td>90</td>
</tr>
<tr>
<td>Low level</td>
<td>45</td>
<td>70</td>
</tr>
<tr>
<td>Very low level</td>
<td>25</td>
<td>50</td>
</tr>
<tr>
<td>No level</td>
<td>0</td>
<td>35</td>
</tr>
</tbody>
</table>

The definition of the membership function for each input and output variable. We use trapezoidal membership function (1):

\[
f_T(x; a, b, c, d) = \begin{cases} 
0, & x \leq a \\
\frac{x - a}{b - a}, & a \leq x \leq b \\
1, & b \leq x \leq c \\
\frac{d - x}{d - c}, & c \leq x \leq d \\
0, & d \leq x 
\end{cases}.
\]

The function of this type characterizes the uncertainty of the form: "approximately equal", "similar to the object", "similar to ...". The lower and upper values define the trapezoidal membership function for each input and output variable. Graphically, the trapezoidal membership function has the following representation (Fig. 5).

Figure 5. Membership functions of trapezoid view

Let us reduce the developed fuzzy rules in table 5.

TABLE 5 \ FUZZY RULE BASE
<table>
<thead>
<tr>
<th>( # )</th>
<th>( x_1 )</th>
<th>( x_2 )</th>
<th>( x_3 )</th>
<th>( y_1 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( 1 )</td>
<td>Excellent result</td>
<td>Excellent result</td>
<td>Excellent result</td>
<td>High level</td>
</tr>
<tr>
<td>( 2 )</td>
<td>Excellent result</td>
<td>Excellent result</td>
<td>Very good performance</td>
<td>High level</td>
</tr>
<tr>
<td>( 3 )</td>
<td>Good result</td>
<td>Excellent result</td>
<td>Excellent performance</td>
<td>High level</td>
</tr>
<tr>
<td>( 4 )</td>
<td>Good result</td>
<td>Excellent result</td>
<td>Very good performance</td>
<td>High level</td>
</tr>
<tr>
<td>( 5 )</td>
<td>Excellent result</td>
<td>Good result</td>
<td>Excellent performance</td>
<td>High level</td>
</tr>
<tr>
<td>( 6 )</td>
<td>Good result</td>
<td>Good result</td>
<td>Very good performance</td>
<td>High level</td>
</tr>
<tr>
<td>( 7 )</td>
<td>Average result</td>
<td>Excellent result</td>
<td>Excellent performance</td>
<td>High level</td>
</tr>
<tr>
<td>( 8 )</td>
<td>Average result</td>
<td>Good result</td>
<td>Excellent performance</td>
<td>Good level</td>
</tr>
<tr>
<td>( 9 )</td>
<td>Good result</td>
<td>Average result</td>
<td>Very good performance</td>
<td>Good level</td>
</tr>
<tr>
<td>( 10 )</td>
<td>Average result</td>
<td>Good result</td>
<td>Good performance</td>
<td>Good level</td>
</tr>
<tr>
<td>( 11 )</td>
<td>Good result</td>
<td>Average</td>
<td>Good</td>
<td>Good level</td>
</tr>
</tbody>
</table>
Transition from fuzziness to specific numeric values. Let us suppose: x1 - the results of tests of current performance, estimated at 52 points;
x2 - the resulting tests, estimated at 47 points;
x3 - control of independent tasks, estimated at 65 points.

Now it is necessary to determine which function is activated and to what extent. In Figure 6, in this case, an example is given of the activation of the membership function of the corresponding term set for the input linguistic variable x1 - “the results of current performance tests”:

\[
\begin{array}{|c|c|c|c|}
\hline
\text{Rule} & \text{x1} & \text{x2} & \text{x3} \\
\hline
12 & \text{Average result} & 0.4 & 0.6 \\
13 & \text{Average result} & 0.8 & 0.4 \\
14 & \text{Good result} & 0.7 & 0.3 \\
15 & \text{Excellent result} & 0.5 & 0.5 \\
16 & \text{Good result} & 0.8 & 0.4 \\
17 & \text{Average result} & 0.3 & 0.1 \\
18 & \text{Good result} & 0.6 & 0.2 \\
19 & \text{Average result} & 0.5 & 0.3 \\
20 & \text{Very low result} & 0.1 & 0.1 \\
21 & \text{Very low result} & 0.1 & 0.1 \\
22 & \text{Very low result} & 0.1 & 0.1 \\
23 & \text{Very low result} & 0.1 & 0.1 \\
24 & \text{Bad result} & 0.1 & 0.1 \\
\hline
\end{array}
\]

Figure 6. Activating the membership function of the input linguistic variable x1 - “test results of current performance”

The following rules are activated in the rule base:

Rule 12: If x1 - Average result And x2 - Average result And x3 - Good performance = min (0.8, 0.4, 0.7) = 0.3

Rule 13: If x1- Average result And x2- Average result And x3 - Very good performance = min (0.8, 0.3, 0.7) = 0.3

Figure 7. Area of intersection for knowledge output values

Now it is necessary to determine the maximum of the function with the minimum value of the argument. We get the value of y1 = 0.4 (in the numerical representation - 48).

IV. CONCLUSION

In this paper, brief concepts of a linguistic variable, its tuple are given, and characteristics are given to the components of a tuple. The knowledge of the linguistic variable is expanded, the scope of the linguistic variable is expanded. An analysis of approaches to assessing the level of knowledge has been carried out and a fuzzy system of knowledge control has been developed on the basis. An example of the parameters by which the assessment of knowledge can be carried out.

The use of the developed fuzzy system with the involvement of experts will allow the consumer of educational services to carry out a timely assessment of the level of knowledge obtained in the learning process, and, accordingly, adjust the learning path.

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References


