APPLICATION OF FUZZY LOGIC IN IDENTIFICATION OF GIFTED STUDENTS

1 Introduction and description of reseach problem

Defining giftedness, it is most often described as an individual's ability, which is quantitatively and qualitatively more developed in comparison with their peers, in a specific area valued by the socio-cultural environment (Heward 2013). According to Porter (Porter 1999), these definitions may acquire more concrete form in connection with their conception. It may be either liberal vs. conservative conception (estimates of the amount of the gifted in the population differ), mono - vs. multidimensional (according to the amount of the criteria for the giftedness identification), the definition of potential vs. manifested performance. Our conception of giftedness and it is conceived in the sense of a high ability in the intellect area.

The article deals with the problem of gifted student and its identification. The process of gifted student identification is one of the most important parts of growing up gifted individuals because the outcome is inclusion into the special broad educational program in a form of special school for gifted students or another enriching curriculum. The process of identification must be an elaborate system of each school or institution in which they are addressed organizational, conceptual, ethical and also the methodological issues in which we will focus.

During the identification process the pedagogical, psychological and mixed identification methods are used, for example didactic tests, tests of intelligence, tests of achievement, interviews, observation, nomination, etc. Each method follows several criteria. For example teacher nomination could contain partial criteria as a learning quality, logical thinking, text comprehension, creativity and motivation (Callahan and Renzulli 2012).

During evaluation of partial identification outputs (criteria) the broad model is suggested (Renzulli and Reis 2004). In the broad model the gifted individual must fulfil all or the most of identification criteria, so the methodological problem is how to combine these each results.

In praxis and theory (Callahan and Renzulli 2012) is application of the additive model registered. In this model the partial outcomes are easily added for each individual in identification process. These outputs in a form of some total points are compared, so the individuals with the best results are nominated into the special education form. The advantage of additive model is quite easy evaluation, where we add each point together. On the other hand we add the criteria with different conditions and relevance (for example logical thinking and motivation), moreover the results from each different criteria could be inappropriately compensate and give mistaken results of identification process.

Hunsaker (Hunsaker 2012) notes, that different identification criteria cannot be added linearity. He suggests addition of selected criteria which plays key role for identification of gifted students and other less important criteria which are used tentatively.

2 Suggestion of solution of problem

To eliminate these disadvantages we suggest combining each result by using the fuzzy logic. The method allows to clear evaluation of larger number of data without compensation of variables. Its advantage comes from using of vague variables and in used identification method.

We found that there were no application of the fuzzy logic during identification process of gifted individuals according to analyze of available article database (EBSCO, XERXES and Proquest). There are no articles worldwide concerning identification of gifted student via computer aided processing. The buildup model enables evaluation of many students from databases and makes the evaluation objective and unified. The fuzzy logic outperformed identification process of gifted people by other methods mentioned in (Callahan and Renzulli 2012; Renzulli and Reis 2004; Hunsaker 2012) from this point of view.

3 The way of the use of fuzzy logic

In classical logic, a theory defines a set as a collection having certain definite properties. Any element belongs to the set or not according to clear-cut rules; membership in the set has only the two values 0 or 1. Later, the theory of fuzzy logic was created by Zadeh in 1965. Fuzzy logic defines a variable degree to which an element x belongs to the set. The degree of membership in the set is denoted $\mu(x)$; it can take on any value in the range from 1 to 0, where 0 means absolute non-membership and 1 full membership. The use of degrees of membership corresponds better to what happens in the world of our experience. Fuzzy logic measures the certainty or uncertainty of how much the element belongs to the set. People make

analogous decisions in the fields of mental and physical behaviour. By means of fuzzy logic, it is possible to find the solution of a given task better than by classical methods.

The fuzzy logic system consists of three fundamental steps: fuzzification, fuzzy inference, and defuzzification. See Fig. 1.

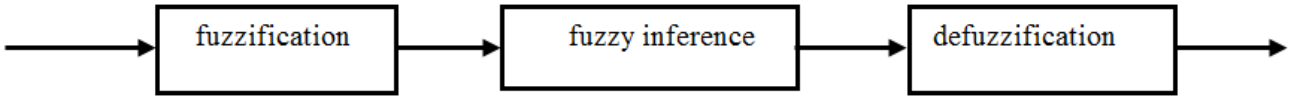

Fig. 1 Decision making solved by means of fuzzy logic

The first step (fuzzification) means the transformation of ordinary language into numerical values. For variable gifted student, for example, the linguistic values can be low, medium, high gifted student. The variable usually has from three to seven attributes (terms). The degree of membership of attributes is expressed by mathematical functions. There are many shapes of membership functions. For example, for mf1, P = [0 0 3]; mf2, P = [2 4 6]; mf3, P = [4 6 7 9]; mf4, P = [8 10 10]; and so forth. See Fig. 2. These membership functions are used in identification.

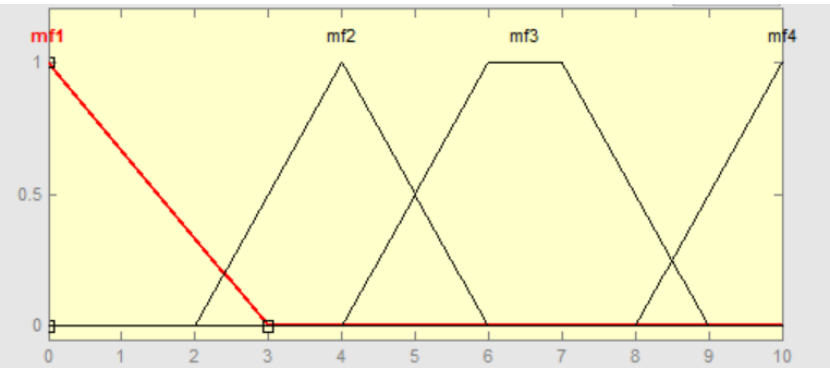

Fig. 2 The types of membership functions Λ and Π

The types of membership functions that are used in practice are for example Λ and Π. There are many other types of standard membership functions on the list including spline ones. The attribute and membership functions concern input and output variables. Three inputs *Learning*, *Thinking* and *Creativity* are used.

The second step (fuzzy inference) defines the system behaviour by means of the rules such as <IF>, <THEN>, <WITH>. The conditional clauses create this rule, which evaluates the input variables. These conditional clauses have the form

<IF> I_1 is mf_a <AND> I_2 is mf_b . . . < AND> I_{N-1} is mf_y < AND >I_N is mf_z <THEN> O_1 is mf_{O1} <WITH> s.

The written conditional clause could be described by words: If the input I_1 is mf_a and I_2 is mf_b and . . . and I_{N-1} is mf_y and I_N is mf_z then O_1 is mf_{O1} with the weight s, where the value s is in the range <0–1>. These rules must be set up and then they may be used for further processing.

The fuzzy rules represent the expert systems. Each combination of attribute values that inputs into the system and occurs in the condition <IF>, <THEN>, <WITH> represents one rule. Next it is necessary to determine the degree of supports for each rule; it is the weight of the rule in the system. It is possible to change the weight rules during the process of optimization of the system. For the part of rules behind <IF>, it is necessary to find the corresponding attribute behind the part <THEN>. These rules are created by experts. The <OR> could be instead <AND>. The twenty seven rules with operators <IF>, <AND> and <THEN> are used in build-up model.

The third step (defuzzification) means the transformation of numerical values to linguistic ones. The linguistic values can be, for example, for variable *Rate of Talent (RT)* is low, medium and high. The purpose of defuzzification is the transformation of fuzzy values of an output variable so as to present verbally the results of a fuzzy calculation. During the consecutive entry of data the model with fuzzy logic works as an automat. There can be a lot of variables on the input. The output *Rate of Talent* is used.

The proposed model is based on fuzzy logic and fuzzy sets. A fuzzy set A is defined as (U, μ_A), where U is the relevant universal set and μ_A: $U \rightarrow \langle 0,1 \rangle$ is a membership function, which assigns each element from U to fuzzy set A. The membership of the element $x \in U$ of a fuzzy set A is indicated $\mu_A(x)$. We call $F(U)$ the set of all fuzzy set. Then the "classical"

set A is the fuzzy set where: μ_A: $U \rightarrow \{0, 1\}$. Thus $x \in A \Leftrightarrow \mu_A(x) = 0$ and $x \notin A \Leftrightarrow \mu_A(x) = 1$. Let U_i, $i = 1, 2, ..., n$, be universals. Then the fuzzy relation R on $U = U_1 \times U_2 \times ... \times U_n$ is a fuzzy set R on the universal U.

The fuzzy logic theory is described in many books such as (Zadeh 1965; Zadeh 2012). The fuzzy application in non-technical field is described in (Dostál 2011; Dostál 2014), but no book in a pedagogical field.

4 Case study

The case study represents process of identification of many students in the school subject language and communication from school classes. We used the "nomination method" for identification of gifted students. In "nomination method" the class teacher evaluates all students in nine criteria (learning quality, logical thinking, creativity in spoken and written expressions, broad vocabulary application, text comprehension, knowledge of subject language and literature, reading, speaking, activity and motivation) which has 5 levels (scale A-B-C-D-E), where A is extraordinary level and E is inadequate level.

We suggested the fuzzy models that has three inputs with five attributes E - very low (vl), D - low (l), C - medium (m), B - high (h) and A - very high (vh). The individual weights of variables were set up by the experts on gifted students' identification.

Table 1 Criteria of the nomination method (specific)

Criterion:	Weight
1. learning quality	(0.0 – 1.0)
2. logical thinking	(0.0 – 1.0)
3. creativity in spoken and written expressions	(0.0 – 1.0)
4. broad vocabulary application	(0.0 – 1.0)
5. text comprehension	(0.0 – 1.0)
6. knowledge of subject Czech language and literature	(0.0 – 1.0)
7. reading	(0.0 – 0.3)
8. speaking	(0.0 – 0.3)
9. activity and motivation	(0.0 – 0.3)

Table 2 Summed criteria of the nomination method (general)

Summed criteria	Criteria	Weights
Learning L	1–3	(0.0 – 1.0)
Thinking T	4–6	(0.0 – 1.0)
Creativity C	7–9	(0.0 – 0.3)

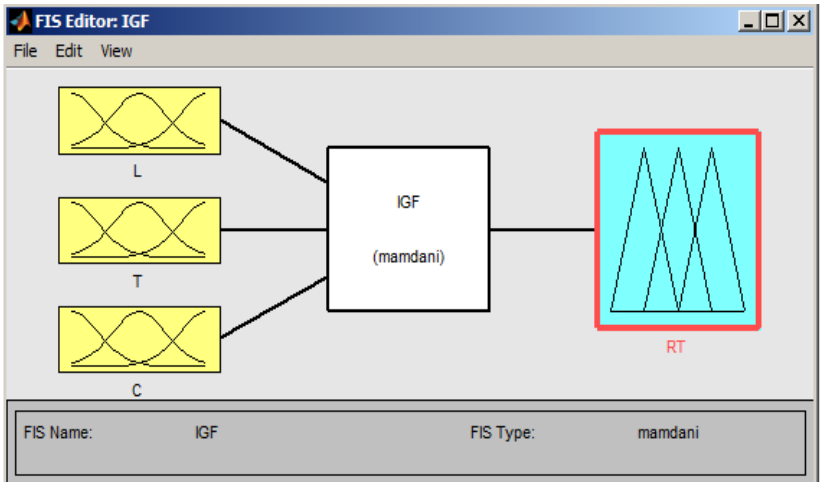

Fig. 3 IGF Model

The application of identification of gifted students (IGF model) via fuzzy interface system is a result of deep analyses and it has three inputs *L-Learning*, *T-Thinking*, *C-Creativity* and one output *RT-Rate of Talented*. See Figure 3.

The fuzzification, defuzzification and fuzzy inference are represented by following steps:

4.1 Fuzzification for *L (Learning)*

The input *L* presents learning as a sum of criteria 1-3 and it has five attributes very low (vl), low (l), medium (m), high (h) and very high (vh) level of learning. See Table 3 and Figure 4.

Table 3 Range for *L*

Fuzzy L	Variable	Range
L_{VL}	Very low (vl)	0.0-0.2
L_{L}	Low (l)	0.2-0.4
L_{M}	Medium (m)	0.4-0.6
L_{H}	High (h)	0.6-0.8
L_{VH}	Very high (vh)	0.8-1.0

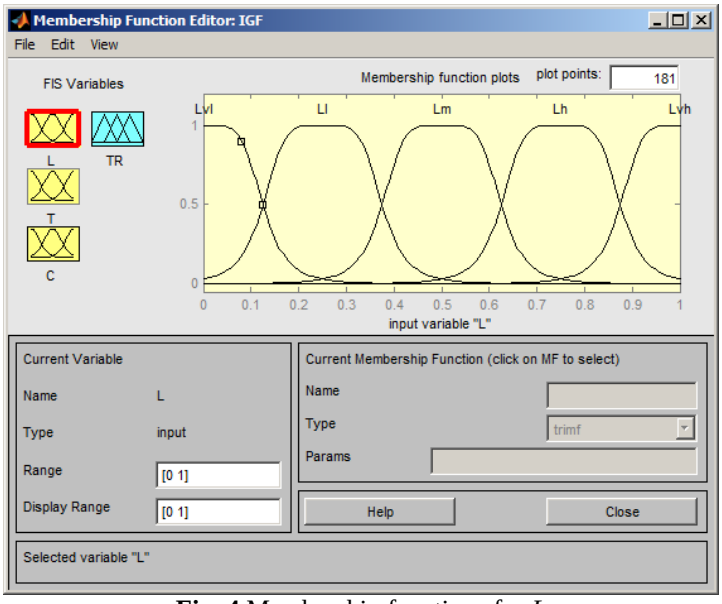

Fig. 4 Membership functions for *L*

4.2 Fuzzification for *T* (*Thinking*)

The input *T* presents thinking as a sum of criteria 4-6 and it has five attributes very low (vl), low (l), medium (m), high (h) and very high (vh) level of thinking. See Table 4. The shapes of membership functions are the same as for the variable L-Learning. See Figure 4.

Table 4 Range for *T*

Fuzzy T	Variable	Range
T_{VL}	Very low (vl)	0.0-0.2
T_{L}	Low (l)	0.2-0.4
T_{M}	Medium (m)	0.4-0.6
T_{H}	High (h)	0.6-0.8
T_{VH}	Very high (vh)	0.8-1.0

4.3 Fuzzification for *C* (*Creativity*)

The input *C* presents creativity as a sum of criteria 7-9 and it has five attributes very low (vl), low (l), medium (m), high (h) and very high (vh) level of creativity. See Table 5. The shapes of membership functions are the same as for the variable L-Learning. See Figure 4.

Table 5 Range for *C*

Fuzzy *C*	Variable	Range
C_{VL}	Very low (vl)	0.00-0.05
C_{L}	Low (l)	0.05-0.01
C_{M}	Medium (m)	0.01-0.15
C_{H}	High (h)	0.15-0.20
C_{VH}	Very high (vh)	0.02-0.03

4.4 Defuzzification for *RT* (*Rate of Talented*)

The output *RT* presents rate of talent it has three attributes low (l), medium (m) and high (h). See Table 6 and Figure 5.

Table 6 Range for *RT*

Fuzzy *RT*	Variable	Range
RT_{L}	Low (l)	0.00-0.25
RT_{M}	Medium (m)	0.25-0.70
RT_{H}	High (h)	0.70-1.00

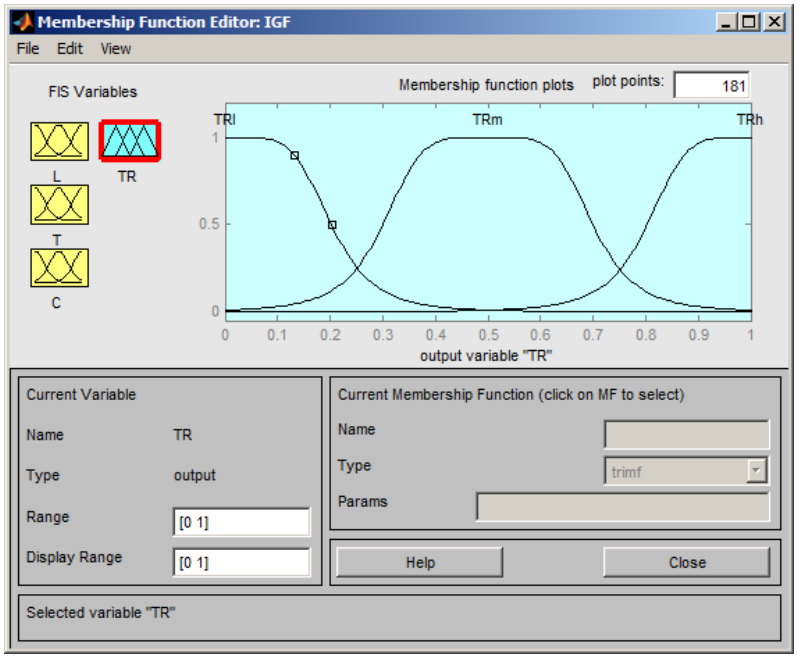

Fig. 5 Membership functions for *RT*

4.5 Fuzzy inference

The fuzzy inference is represented by set ups of rules such as:

If L = vl and T = vl and C = vl then RT = l
If L = l and T = l and C = l then RT = l
If L = m and T = m and C = m then RT = m
If L = h and T = h and C = h then RT = m
If L = vh and T = vh and C = vh then RT = h

and some others. See Figure 6. The total number of rules is twenty seven.

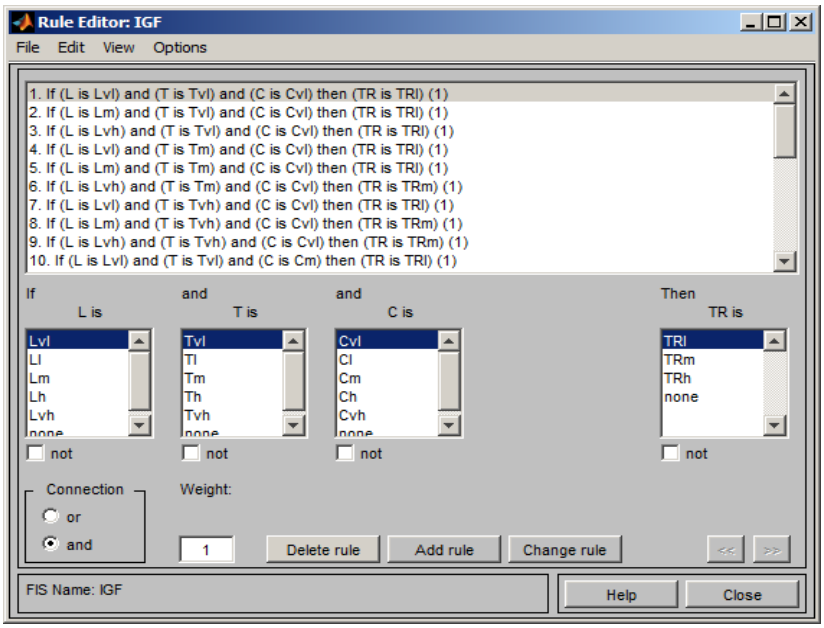

Fig. 6 Set up rules

The fuzzy model was tuned with the help of MATLAB surface viewer, which is three-dimensional graph of two inputs and one output. The rate of talent *TR* is dependent on creativity *C* and thinking *T*. See Figure 7.

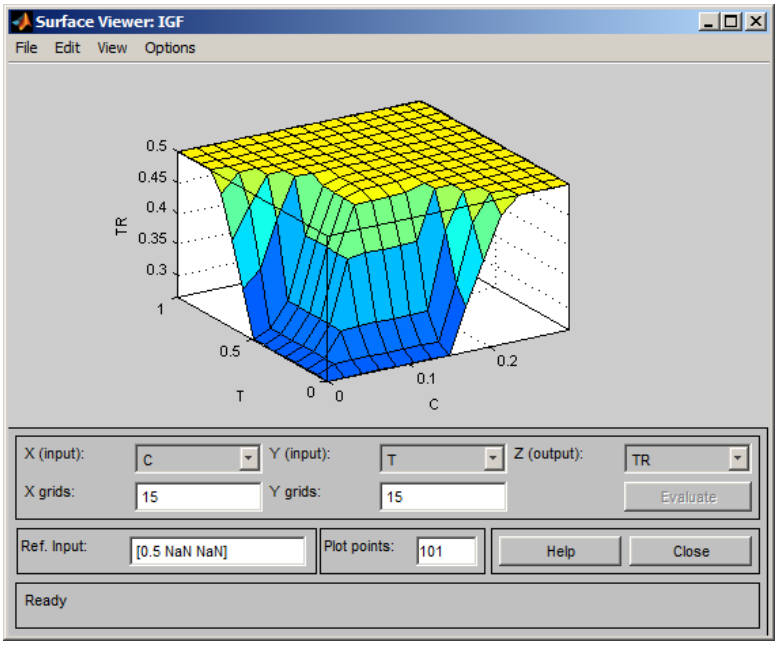

Fig. 7 Surface viewer graph

As an example one of the searched students has following results presented by Table.7.

Table 7 Input data

	1	2	3	4	5	6	7	8	9
	L			*T*			*C*		

A									
B	A	A	A	A		A			A
C					A		A	A	
D									
E									

The results were transformed via simple averaging on the Table 8.

Table 8 Input data

	L	T	C
A			
B	A	A	
C			A
D			
E			

The input values are L = 0.95 (high), T = 0.95 (high) and C = 0.25 (low). The output RT = 0.68 was calculated and it means middle gifted student. The inputs and outputs are presented in Figure 8.

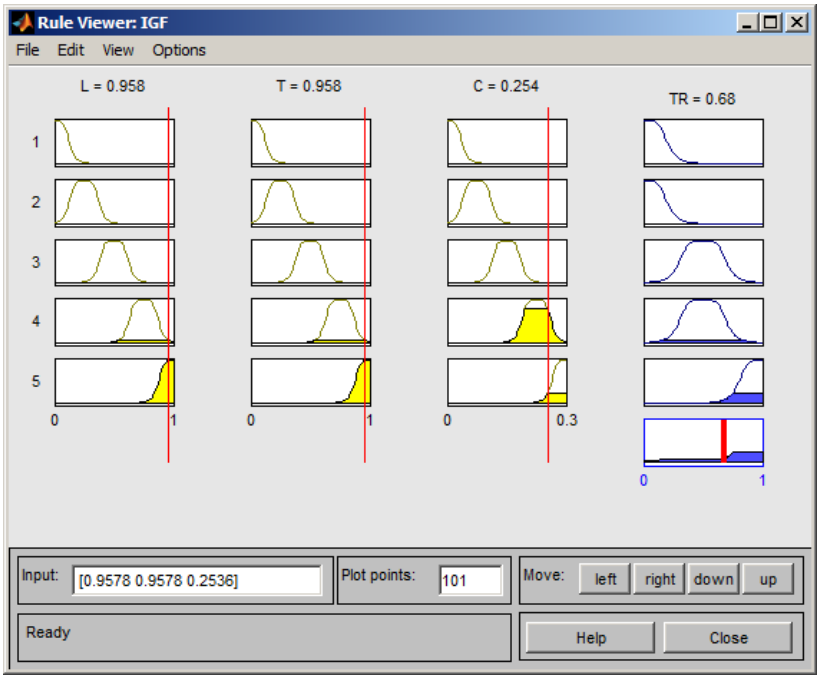

Fig. 8 Rules viewer

It was identified many students and it results in following proportions: 20% for high, 55% for medium and 25% for low gifted students. The results serves to create the groups of high, medium and low talented student and for their specific education.

5 Limitation of research

We are aware that our proposed methodology for the identification of gifted individuals has some limits and constraints, as well as any other method.

The first limit is related to applied conception of giftedness. Our conception is focused on gifted students performance in specified competencies and time (just here and now). Moreover, the other variables based on the environment of student enter into the identification process. It makes actual demonstration of giftedness difficult. We are aware that the method is not suitable for all students. The outputs of identification process couldn´t reliably reflect the real level of giftedness.

The other limit comes from weights of importance and it is subjective setting by experts in problem of giftedness. In relation to the different concepts of giftedness could from weights of importance differ from each other, but when it stays constant during the process of evaluation, it is not limitation.

It is necessary to set up the variables related to identification and transform them to nominal data, which could be measurable. Therefore, the pedagogical reality simplified, as well as using any other separated method.

6 Conclusion

In this article we presented the process of identification of students in the school subject language and communication from ordinary school classes. We used the nomination method for identification of gifted students, in which the class teacher evaluated all students in nine criteria (in 3 general areas: *Learning L*, *Thinking T* and *Creativity C*) which has 5 levels (scale A-B-C-D-E), where A was extraordinary level and E inadequate level.

We didn´t use "additive model", which is applied in many identification process, because of inappropriately compensation of each results of identification process.

For evaluating results from nine different identification criteria we used the fuzzy logic. The method allowed to clear evaluation of larger number of data without compensation of variables. This computing method is very suitable for mentioned purposes and it leads to higher quality of analyses and identification of students and educational process themselves.