



# Neuro-fuzzy recruitment system

## Sistema de reclutamiento *Neuro-Difuso*

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#### ABSTRACT:

The methods of recruitment in various fields of activity were analyzed, and a trend towards methods of assessing the quality of candidates based on the application of hybrid technologies was identified. Brief data describing the action of a neuro-fuzzy hybrid system like the adaptive network-based fuzzy inference system (ANFIS), which combines the principles of fuzzy logic and artificial neural networks, was given. The importance of the characteristics of a candidate for the position was defined using the data mining technique, and the possibility for assessing the quality of workers in the field of the knowledge-based industry through the neuro-fuzzy ANFIS network was shown. Based on the results of the neuro-fuzzy solution, the regression equation was derived which connects the quality of a candidate with his/her characteristics. The comparison of the quality assessments of an applicant for the position in the organization, obtained by neuro-fuzzy modeling and by the regression method, was conducted.

**Keywords:** recruitment, neuro-fuzzy system, selection of characteristics, quality assessment, regression equation.

#### RESUMEN:

Se analizaron los métodos de reclutamiento en diversos campos de actividad y se identificó una tendencia hacia los métodos de evaluación de la calidad de los candidatos basados en la aplicación de tecnologías híbridas. Se proporcionaron datos breves que describen la acción de un sistema híbrido neuro-difuso como el sistema de inferencia difusa basado en la red adaptativa (ANFIS), que combina los principios de lógica difusa y redes neuronales artificiales. La importancia de las características de un candidato para el puesto se definió utilizando la técnica de minería de datos, y se mostró la posibilidad de evaluar la calidad de los trabajadores en el campo de la industria del conocimiento a través de la red neuro-difusa ANFIS. Con base en los resultados de la solución neuro-difusa, se derivó la ecuación de regresión que conecta la calidad de un candidato con sus características. Se llevó a cabo la comparación de las evaluaciones de calidad de un solicitante para el puesto en la organización, obtenido por modelado neuro-difuso y por el método de regresión.

**Palabras clave:** reclutamiento, sistema neuro-difuso, selección de características, evaluación de calidad, ecuación de regresión.

## 1. Introduction

Any organization requires resources, including finance, raw materials, equipment and

personnel, for successful functioning. Researchers in the field of human resources management believe that the quality of personnel is a strategic solution because it affects the organization efficiency, e.g., customer satisfaction, innovations, profitability and competitiveness of the company. In the global competitive environment, the bigger part of success of well-known companies is due to their competence and personnel ability. Competence includes the required attributes, particularly knowledge, skills, personal and behavioral factors necessary for persons to perform their role in the organization.

Human resources management refers generally to the identification, assessment, selection, employment, motivation, training and development of employees to the goals of the enterprise. It should be also noted that organizations faced the growing global competition in human resources (Khorami & Ehsani 2015).

The personnel selection process is aimed at choosing the best potential employee (candidate) to fill the vacant positions. A variety of approaches which help organizations make decisions on how to properly place people in suitable positions was developed. Some firms take a strategic decision to choose the best candidate using rigorous and costly selection procedures, while others decide to fill the positions quickly and cheaply based solely on the information stated in questionnaires.

The identification and assessment of candidates, meeting the requirements, can be considered as a function of personnel selection. The characteristics of candidates for the position play an important role in the success of an organization. It is very difficult to correct the consequences of wrong decision in hiring employees. One of the main goals of the organization is finding more powerful ways of assessing and recruiting personnel. In a changing world, the choice of suitable and well-trained personnel has become more important than before. Qualified and committed employees play an important role in achieving visible success for their companies (Dereli, Durmuşoğlu & Seçkiner 2010).

Currently, when recruiting personnel, various methods are used, in particular multi criteria decision making method (MCDM), analytic hierarchy process (AHP), technique for order preference by similarity to ideal solutions (TOPSIS), expert systems (ES), artificial neural networks (ANN), fuzzy logic (FL) (Afshari, Nikoli, & Cockalo 2014).

However, in the context of a changing environment, decision makers face difficulties with the formation of clear answers as assessment criteria, so in the recruitment tasks there is a tendency to use hybrid systems, e.g. neuro-fuzzy systems of the ANFIS type (Martínez, Rodríguez-Díaz, Licea, & Castro 2010; Abbasi & Asgari 2014; Ravichandran, Suresh, & Sekr 2012).

Next, the paper is organized as follows. The principle of operation of the ANFIS hybrid system is considered at first. Further the selection of the number of parameters describing the characteristics of a candidate for the position is performed. Then, using the ANFIS network, the quality of the test candidate is calculated. In the end, the equation linking the candidate's quality with his/her characteristics is derived.

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## **2. Methodology**

A hybrid network combining the principles of neural networks and fuzzy logic is a multi-layer neural network of a special structure without feedbacks, in which ordinary (nonfuzzy) signals, weights and activation functions are used. The main idea, used in the model of hybrid networks, is in applying the existing data sample to determine the parameters of membership functions which fit a particular fuzzy inference system best of all. To find the parameters of membership functions, the known procedures for training neural networks are used.

By introducing the fuzzy inference system into the structure of adaptive networks, we shall come to the ANFIS architecture (Jang, Sun & Mizutani 1997). The ANFIS system is one of the first diagrams of hybrid neuro-fuzzy networks: a neural network of special propagation. The idea of neuro-fuzzy systems is to determine the parameters of fuzzy systems by training

methods used in neural networks. Thus, the ANFIS method has all the advantages inherent in the fuzzy inference systems and neural networks.

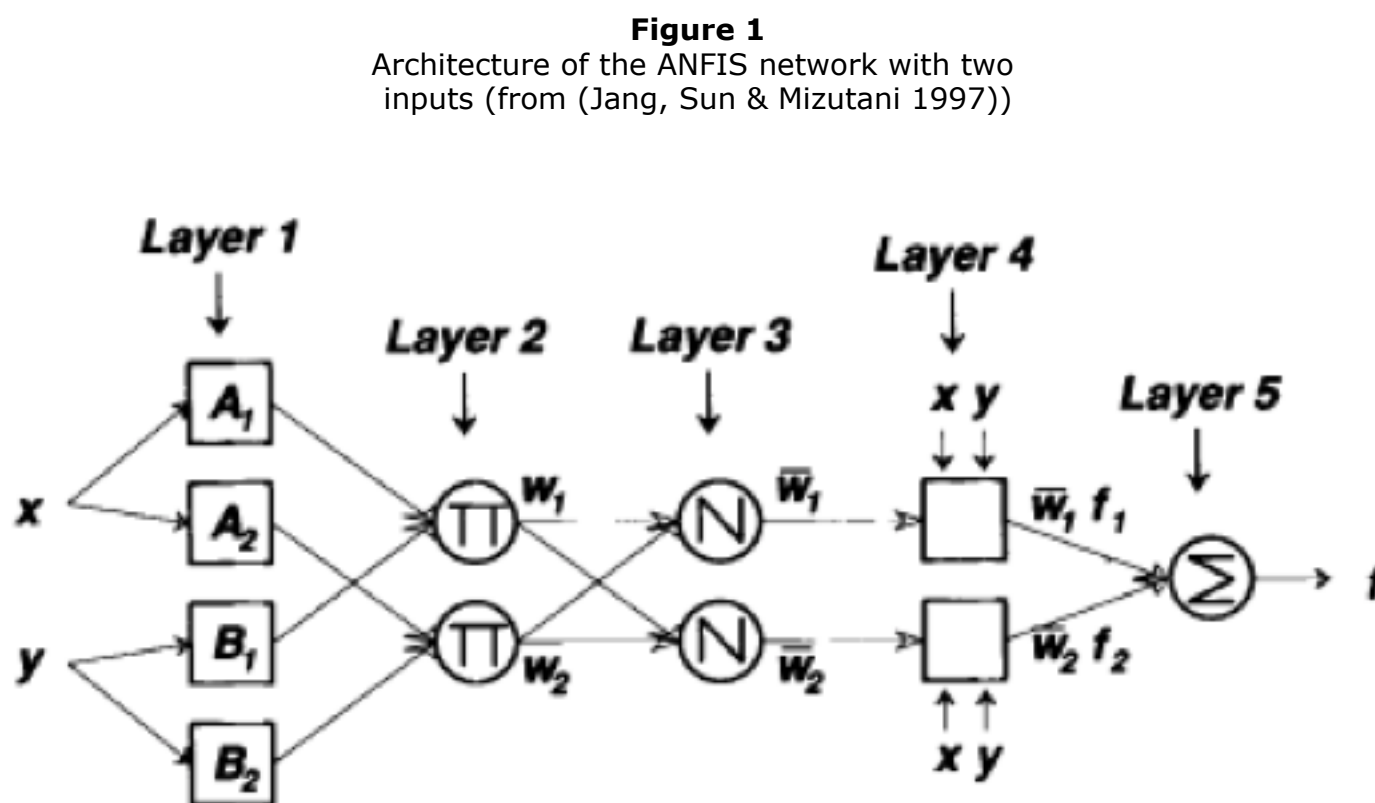
The mechanism of fuzzy logic can be implemented using the algorithm of the Mamdani or Sugeno type. The main difference between the Mamdani and Sugeno output systems is in the way of crisp output obtaining. In the Mamdani algorithm, the crisp output value is obtained through defuzzification of the output fuzzy set. In the Sugeno algorithm, the weighted average value is formed at the output.

The ANFIS implements the Sugeno fuzzy inference system in the form of a five-layer feed forward neural network.

The purpose of layers is as follows:

- the first layer – terms of the input variables;
- the second layer – antecedents (parcels) of fuzzy rules;
- the third layer – normalization of degrees of rules execution;
- the fourth layer – inference of rules
- the fifth layer – the output variable.

Figure 1 shows the ANFIS network with two input variables and two fuzzy rules.



A typical fuzzy rule in a Sugeno fuzzy model has the form:

$$\text{if } x \text{ is } A \text{ and } y \text{ is } B \text{ then } z = f(x, y),$$

where  $A$  and  $B$  are fuzzy sets in the antecedent;  $Z = f(x, y)$  is a crisp function.

Usually the function  $f(x, y)$  is a polynomial of the input variables. When  $f(x, y)$  is a first-order polynomial, the resulting fuzzy inference system is called a first-order Sugeno fuzzy model.

For simplicity, let us assume that the concerned fuzzy inference system has two inputs  $x$  and  $y$  and one output  $z$ . For this model, two fuzzy rules have the form

$$\text{Rule 1: if } x \text{ is } A_1 \text{ and } y \text{ is } B_1 \text{ then } f_1 = p_1x + q_1y + r_1,$$

$$\text{Rule 2: if } x \text{ is } A_2 \text{ and } y \text{ is } B_2 \text{ then } f_2 = p_2x + q_2y + r_2.$$

Let us consider the work of individual layers of the ANFIS system (Jang, Sun & Mizutani 1997).

*The 1st layer.* Each node in the first layer of the ANFIS system processes the incoming input data  $x$  and  $y$ . The  $A_i$  and  $B_i$  values define fuzzy sets. (We denote the output of the  $i$ -th node in the layer  $l$  as  $O_{l,i}$ ).

The node  $i$  in this layer is an adaptive neuron with the output

$$O_{1,i} = \mu_{A_i}(x), \text{ for } i = 1, 2 \text{ or}$$

$$O_{1,i} = \mu_{B_{i-2}}(y), \text{ for } i = 3, 4,$$

where  $x$  (or  $y$ ) is the input to the node  $i$ ;  $A_i$  (or  $B_i$ ) is a linguistic term associated with this node.

*The 2nd layer.* This layer is a layer of rules, the inputs of which are outputs of the first layer. Each node in this layer, denoted as  $\Pi$ , determines the product of the input signals

$$O_{2,i} = w_i = \mu_{A_i}(x)\mu_{B_i}(x), i = 1, 2.$$

*The 3rd layer.* In this layer, the output values of neurons of the previous layer are used as inputs. Each neuron of this layer, labeled as  $N$ , computes the relative degree of execution of the fuzzy rule

$$O_{3,i} = \bar{w}_i = \frac{w_i}{w_1 + w_2}, i = 1, 2.$$

*The 4th layer.* The node  $c$  with the index  $i$  in this layer computes the contribution of the  $i$ -th rule to the overall result

$$O_{4,i} = \bar{w}_i f_i = \bar{w}_i (p_i x + q_i y + r_i),$$

where  $\bar{w}_i$  is the output of the 3rd layer;  $p_i, q_i, r_i$  are parameter set of this node.

*The 5th layer.* The only node in the last layer, labeled as  $\Sigma$ , sums the outputs of the previous layer and thus determines the output value of the ANFIS system

$$O_{5,i} = \sum_i \bar{w}_i f_i = \sum_i w_i f_i / \sum_i w_i.$$

In work, the network of ANFIS type is used to generate assessments of the candidate quality.

## 3. Results

### 3.1. Data preparation

The analysis of literature data in the field of recruitment allows identifying the most characteristic features of candidates for a particular position. Despite the different scope, which

naturally leads to different parameter sets, it is possible to identify a certain trend. Table 1 shows various lists of candidates' characteristics.

**Table 1**  
Characteristics of candidates for specific positions

No. of subitem	The scope	Characteristics	Source
1	Engineer of system analysis	Emotional balance, skills of speech communication, personality, past experience, self-confidence	Chen (2000)
2	Hypothetical example	Fear of testing, personal qualities, annual salary, desire for leadership, work experience, skills of speech communication, proficiency in computer, knowledge of a foreign language	Karsak (2001)
3	Travel agency	Education, working knowledge, geographic knowledge, ability to foresee the situation, computer skills, knowledge of office equipment, balance	Butkiewicz (2002)
4	Assessment of management capabilities	Characteristics of abilities, personal traits, motivation, competence, communication skills, technical level	Huang <i>et al.</i> (2004)
5	Social learning	Age, education, additional education, previous work experience, foreign language, computer knowledge	Drigas <i>et al.</i> (2004)
6	The post of university professor	Publications and research, pedagogic skills, practical experiences in industries and corporations, past teaching experience, teaching discipline	Saghafian and Hejazi (2005)
7	Bank credit expert	Experience in credit analysis, annual salary, personal profile, leadership abilities, communication skills, education, age, knowledge of foreign languages	Polychroniou and Giannikos (2009)
8	The area of research and developments (R & D)	Working efficiency, education, training, work experience, availability of degrees and grades, age, innovative potential, loyalty	W. Dejiang (2009)
9	Production engineer	Emotional balance, leadership, self-confidence, communication skills, personal profile, past experience, general abilities, understanding tasks	Dursun and Karsak (2010)

10	Academic staff	Self-confidence, age, team work, academic experience, technical information, writing research papers, oral presentation, bachelor's degree, foreign language	Rouyendegh and Erkan (2013)
11	Hypothetical example	Employee satisfaction with advancement opportunities, skills of employees, creating results by using knowledge, inner relationship, percentage of employees with access to training and development	Pant <i>et al.</i> (2014)

As can be seen from the analysis of Table 1, most employers pay attention to the age, education, work experience, knowledge of a foreign language, skills of work with computer and specific requirements due to the area of use of a candidate for the position.

To illustrate the work of the proposed method, we use the data on the personnel of a computer company, mainly dealing with software products development. As characteristics to be possessed by a candidate for the vacant position in this company, we choose the following: X1 – age (Age); X2 – education (Edu); X3 – experience (Exp); X4 – knowledge of a foreign language (Eng); X5 – possession of special skills in programming (Spe); X6 – ability to work in a command (Com).

To assess the importance of the selected parameters, we use the "Feature Selection" module related to the Data Mining technique. The methods implemented in this module were specially developed to process large sets of predictors in problems of classification or regression. We can choose the reduced set of predictors from a large list of candidates not assuming that the relationship between predictors and dependent variables are linear, or even monotonic. Consequently, this module, implemented in the software product Statistica 13, is ideal as a preprocessor for data mining.

First, let us draw up a table of data on the company employees who are currently working and have worked in the past using the services of an expert HR manager. This officer has ranked the company employees, guided by the above characteristics, and has assigned a rating of their workability (quality) by the 10-point scale. Scales of age and experience of the employees were taken in real units (year), assessments for the rest of the characteristics were given by the 10-point scale. In Table 2 in columns 2-7, the values of characteristics of 20 employees are presented, and in column 8 – expert assessment of their workability.

**Table 2**  
The characteristics of the company employees

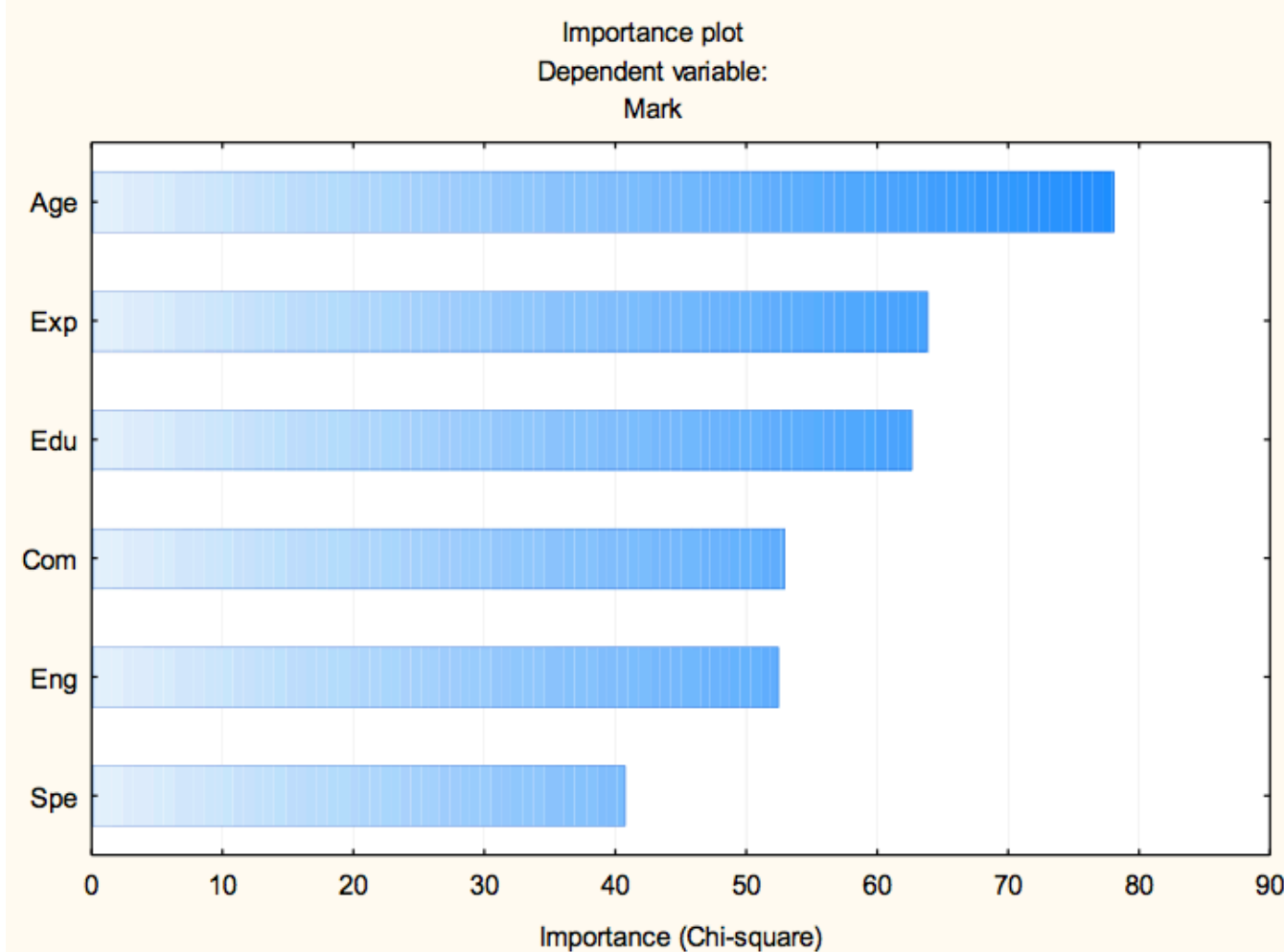
No. of item	Age	Edu	Exp	Eng	Spe	Com	Expert
1	27	6	6	9	6	10	6.0
2	23	7	4	9	8	9	4.0
3	30	6	7	7	6	8	6.0
4	20	1	1	2	2	1	1.0

5	27	6	7	9	9	9	7.0
6	33	10	7	9	6	8	8.0
7	24	5	5	6	2	5	4.0
8	22	2	3	3	3	1	2.0
9	21	1	1	2	2	1	2.0
10	34	7	5	9	10	8	7.0
11	48	7	12	1	9	8	9.0
12	22	2	1	5	3	1	2.0
13	33	8	5	8	7	10	7.0
14	34	10	6	8	7	7	8.0
15	22	6	2	6	5	6	5.0
16	39	6	6	4	7	6	6.0
17	43	8	8	2	8	7	6.0
18	38	6	7	3	7	6	6.0
19	21	2	2	3	2	1	2.0
20	47	6	10	1	9	8	9.0

After processing the data of Table 2, we come to assessment of the importance of candidate characteristics shown in Figure 2.

**Figure 2**  
Importance of characteristics





As can be seen from Figure 2, the most important characteristic is the age of an applicant, further with a small gap, experience and education come, and then ability to work in a command, knowledge of a foreign language and special skills in programming follow. Due to the fact that the initial set consisted of 6 characteristics, there is no need to reduce the number of initial parameters; therefore, in the further analysis we shall retain all the initial characteristics. However, it should be noted that the considered technique can be useful in a situation when the number of initial parameters is significant, and the need for their reduction becomes apparent.

### 3.2. Assessment of the candidate quality

To assess the quality of a candidate for the position, we shall use the ANFIS network and Table 2 showing the source data. The solution to that part of the problem is performed in MatLab R 2012b program.

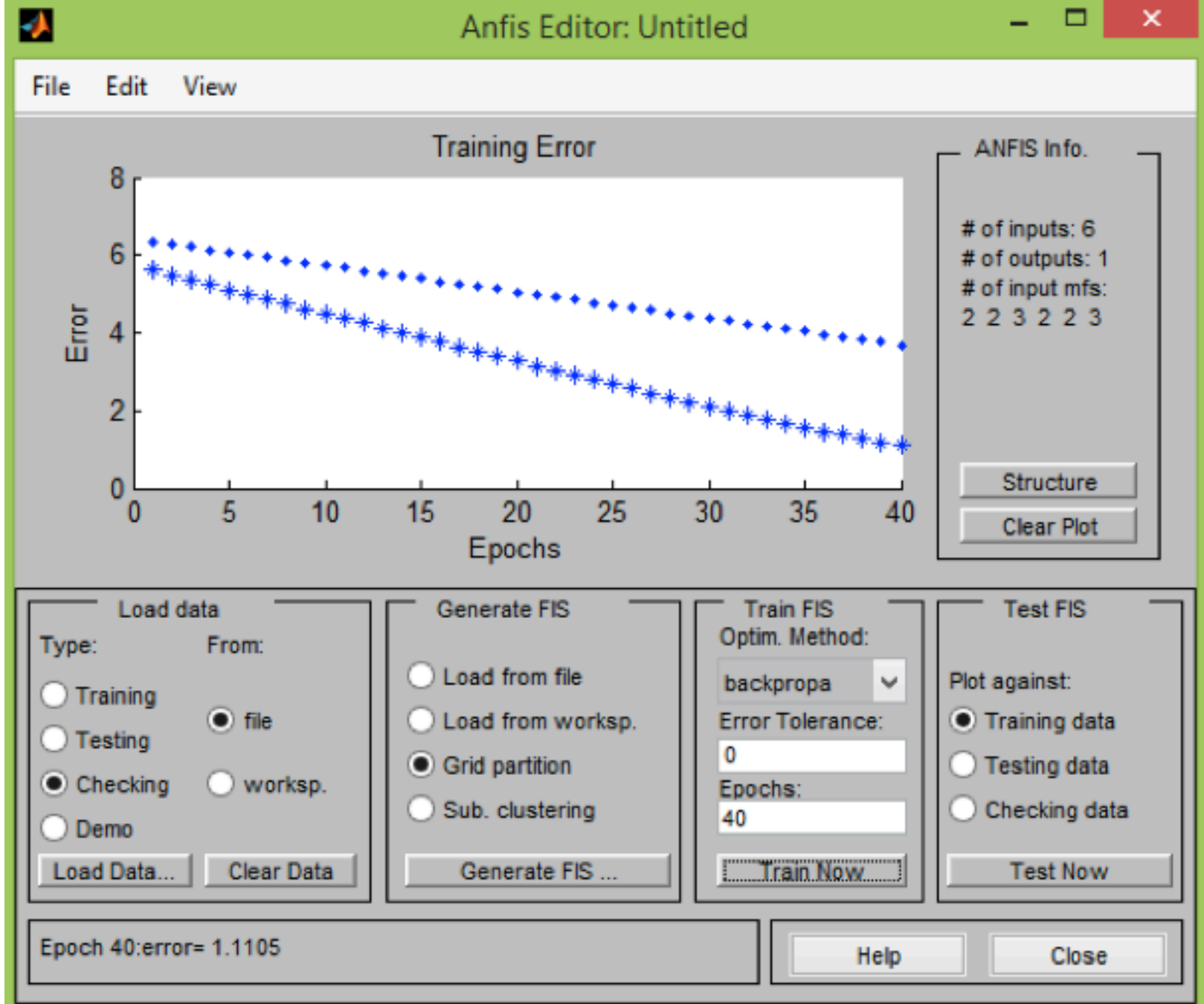
It is worth noting that the modeling approach, used by the ANFIS, is similar to many methods of system identification. First, a hypothesis for the structure of the parametric model (relative to the inputs in the membership function) is made. Second, the inputs/outputs in the form, which is used by the ANFIS for training, are collected there.

To work in the ANFIS system, let us split the source data into two groups: No. 1-13 for training; No. 14-20 – for testing. After downloading all the data into the program, we generate the fuzzy inference system using the Grid partition option. When creating this system, let us use Gaussian membership functions for each of six input variables. The parameters of these functions are configured using the error backpropagation algorithm. We set the numbers of gradations for the input variables as follows: 2; 2; 3; 2; 2; 3, that is, the first input has 2 gradations, the second one – also 2, etc. The total number of rules, which are automatically generated in the ANFIS system, is 144. In the output layer, a linear membership function is used.

The results of training by error backpropagation are shown in Figure 3.

**Figure 3**  
Training schedule

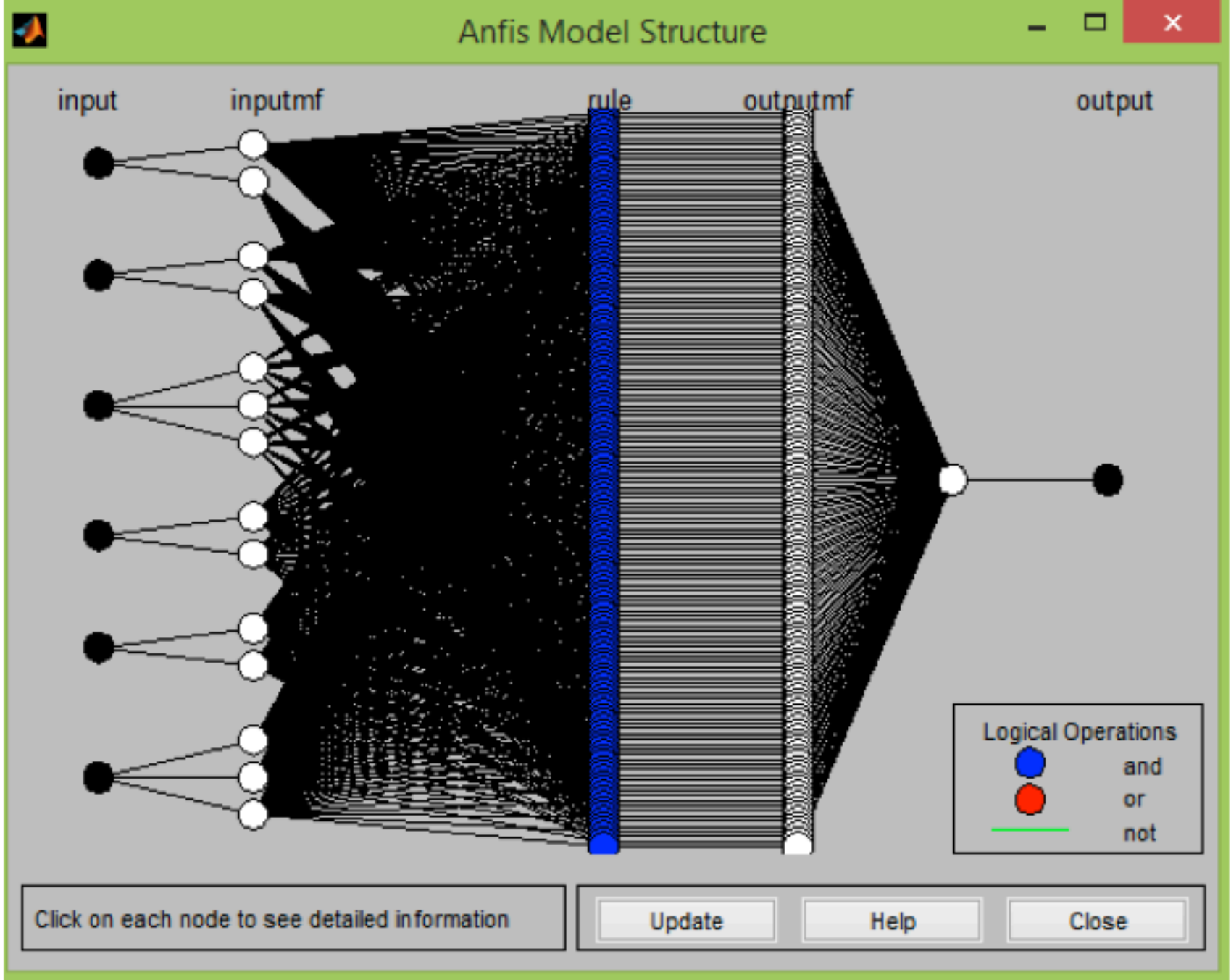




In Figure 3, the upper curve refers to the error in the test sample, the lower one – in the training sample. Because the test error is only reduced, but is not increased, we can come to a conclusion on lack of over-fitting. As can be seen from Figure 3, the training error after 40 epochs is approximately 1.1.

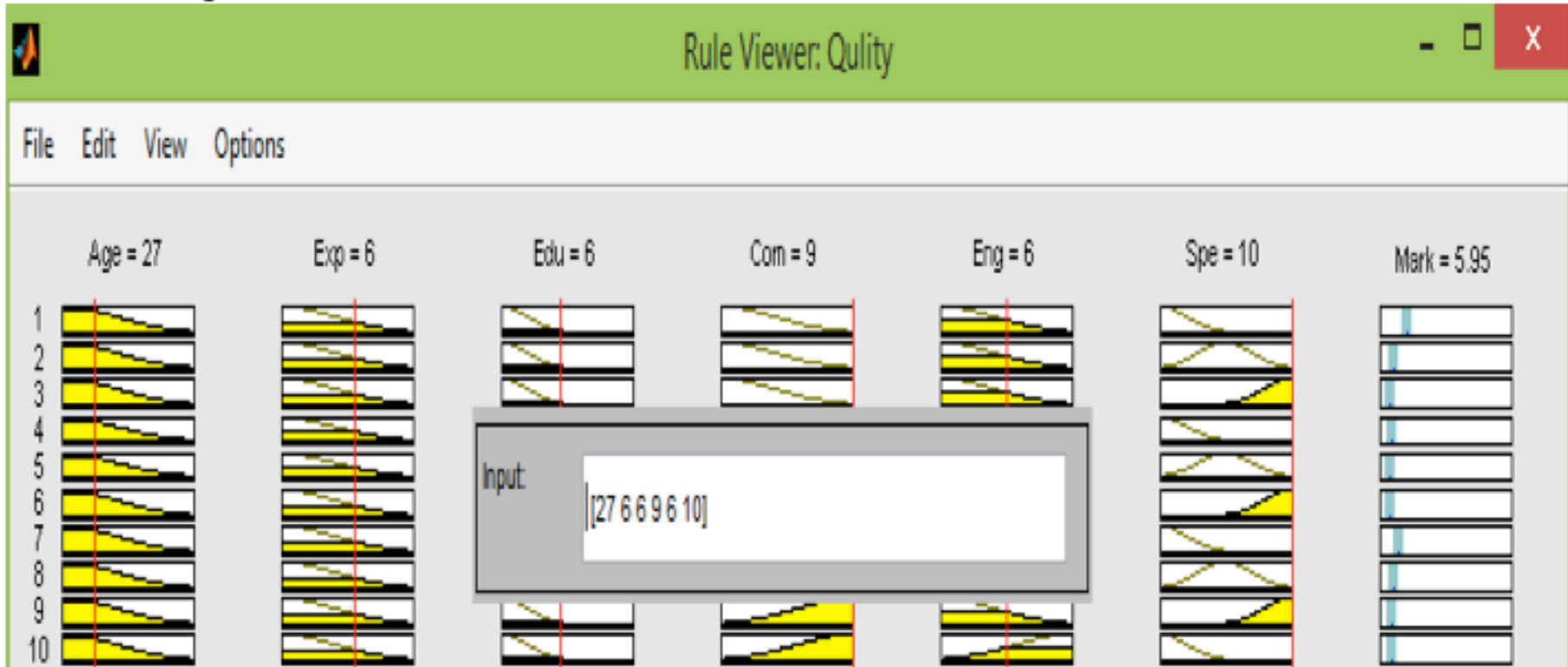
The structure of the formed ANFIS system is shown in Figure 4. The gap between the second and third layers has blackened due to the large number of created rules: 144.

**Figure 4**  
Formed ANFIS system



After training, we can obtain assessment of the candidate quality if we use the rule base and enter an applicant's characteristics in the input box. For example, after entering the first line of the source data from Table 2, we get that the assessment of workability (quality) of this candidate is 5.95 points by the 10-point scale. A fragment of the rule base review is shown in Figure 5.

**Figure 5**  
Quality assessment through the ANFIS



Repeating this procedure for all lines of Table 2 (from 2 to 7 columns), we obtain the assessment of workability of 13 employees who were used as the training sample. Table 3 shows the assessments of employees' workability which were defined through the ANFIS system (column 9).

**Table 3**  
Assessments of employees through ANFIS and regression

No. of item	Age	Edu	Exp	Eng	Spe	Com	Expert	mf-gaus	regres
1	27	6	6	9	6	10	6.0	5.95	5.48
2	23	7	4	9	8	9	4.0	4.78	5.62
3	30	6	7	7	6	8	6.0	4.28	5.19
4	20	1	1	2	2	1	1.0	1.72	1.25
5	27	6	7	9	9	9	7.0	6.96	5.90
6	33	10	7	9	6	8	8.0	6.49	5.63
7	24	5	5	6	2	5	4.0	1.78	2.63
8	22	2	3	3	3	1	2.0	1.31	1.53
9	21	1	1	2	2	1	2.0	1.79	1.34
10	34	7	5	9	10	8	7.0	6.18	6.73
11	48	7	12	1	9	8	9.0	7.98	8.05
12	22	2	1	5	3	1	2.0	1.35	1.46

13	33	8	5	8	7	10	7.0	6.95	6.72
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Thus, at this stage there are two quality assessments:

- determined by the expert way;
- found through the ANFIS.

Subjectivity and dependence on the qualification of an expert refer to the disadvantages of the first assessment; the disadvantage of the second one is the complexity of its formation. Consequently, let us move on to the derivation of the regression equation which links the output parameter with a worker's characteristics.

### 3.3. The regression equation

The equation, linking the output with the input variables, is obtained using the Excel spreadsheet and the data given in Table 3. The found equation has the form:

Regression statistics for this equation are given in Table 4.

**Table 4**  
Regression statistics

Multiple R	0.965255907
R square	0.931718966
Normalized R square	0.863437932
Standard error	0.927986814
Observations	13

As can be seen from Table 4, the determination coefficient has a value equal to 0.93, which indicates a high degree of adequacy of the obtained equation to the data used in its derivation. The quality values, calculated using this equation, are presented in column 10 of Table 3. As follows from the comparison of columns 9 and 10 of Table 3, the data provided in them is close enough to each other taking into account the small amount of the training sample.

## 4. Discussion

Deviations between the results of assessment of an applicant's quality obtained through the ANFIS and regression equation may be due not only to the small size of the sample but also because of using the linear equation. Applying more complex regression may lead to a smaller discrepancy between the assessments. The ANFIS system, leveling the shortcomings of neural networks and fuzzy logic, can also be used in other tasks of management, for example, when assessing the effectiveness of different projects, choosing the development strategies, etc.

## 5. Conclusion

Thus, it was shown that to assess the personnel quality the neuro-fuzzy system of the ANFIS can be used. Besides, the possibility for applying the regression equation, in the derivation of which the assessment obtained by the ANFIS was taken as the output variable, was demonstrated. Since the calculation procedure through the ANFIS is rather time-consuming, the regression estimate can be used for tentative assessment of the employees' quality.

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