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THE ALGORITHM FOR NEURO-FUZZY NETWORK CONSTRUCTION BASED ON MODEL OF CORPORATE BANKRUPTCY RISK ESTIMATION

Анотація. Робота присвячена питанню побудови нейро-нечітких моделей для вирішення різних соціально-економічних завдань. Представлено алгоритм побудови нейронної мережі в пакеті MATLAB. Побудована модель оцінки загрози банкрутства корпорацій на основі нейро-нечітких мереж.

Аннотация. Работа посвящена вопросу построения нейро-нечетких моделей для решения различных социально-экономических задач. Представлен алгоритм построения нейронной сети в пакете MATLAB. Построена модель оценки угрозы банкротства корпораций на основе нейро-нечетких сетей.

Abstract. The paper is devoted to the construction of neuro-fuzzy models for solving various socio-economic problems. The algorithm for constructing a neural network in the MATLAB package is presented. A bankruptcy risk assessment model for corporations based on neuro-fuzzy networks is built.

Ключові слова: алгоритм, банкрутство, корпорація, криза, MatLab, модель, оцінка, прогнозування, фактори.

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Keywords: algorithm, bankruptcy, corporation, crisis, estimation, MatLab, model, factors, forecasting.

In conditions of an unstable economy, characterized by frequent changes in macroeconomic circumstances, management decisions are made under uncertainty, which makes the task of planning economic activity and forecasting its results as one of the most difficult and ambiguous. In addition, the problem of early detection and prevention of the negative effects of financial crises on enterprises and, consequently, the prevention of insolvency and bankruptcy as an extreme stage of their development are exacerbated. Today, in Ukraine, regardless of the scale of business activity, there is an increase in the number of bankrupt enterprises, and every second enterprise receives a negative financial result.

There is a number of classical forecasting methods based on the mathematical statistics apparatus, among which are methods of analysis and modelling of time series, methods of multidimensional regression analysis [5]. The peculiarity of these methods is the need for a clear specification of models, also the additional difficulty of using these methods creates the unsteadiness of the studied economic processes. Different types of intellectual systems have their own peculiarities, which makes them most suitable for solving certain classes of problems and less suitable for others.

But at the same time with technological progress, researchers have started to pay more attention to artificial intelligence, among them the most popular one are neural networks that have proven themselves well for object identification tasks, but at the same time they are very inconvenient to explain how they perform such identification. Systems with fuzzy logic, on the contrary, are practical for explaining their conclusions, but they cannot automatically acquire the knowledge to use them in output mechanisms. This reasoning formed the basis for the creation of fuzzy neural network apparatus, in which conclusions are drawn on the basis of fuzzy logic apparatus, but the corresponding membership functions are adjusted using neural network learning algorithms [7].

Fuzzy logic allows to formalize qualitative information from expert economists for a particular field of application, and to present a set of acquired knowledge in the form of a system of fuzzy rules of inference that allow you to analyze the conclusions obtained in the course of operation of the hybrid intellectual system [11].

Neural networks provide the ability to display algorithms of fuzzy inference in the structure of the neural network, entering in the information field of the neural network data received from expert economists. The knowledge base formed in such way is automatically adjusted in the course of learning the neural network, and may be subjected to further analysis based on the real values of the analyzed economic indicators and the results of the correction [8].

Using fuzzy data, the inputs and outputs, as well as the weights of such networks, are fuzzy numbers. Network training is conducted using the same optimization methods that are used in the training of conventional neural networks. However, the algorithm for modifying weights is more cumbersome and complex [10].

Hybrid neuro-fuzzy systems have found the largest scope among all possible methods for fuzzy sets and neural networks synthesis. This is due to the fact that they allow the fullest use of the strengths of fuzzy systems and neural networks. A characteristic of hybrid systems is that they can always be regarded as systems of fuzzy rules, and the tuning of membership functions in the preconditions and conclusions of rules based on the set of learning is done through neural networks. There are several hybrid systems architectures, each designed to solve its own range of problems. This creates some difficulties in the study and application of these systems [12].

The most common and convenient software package for building neuro-fuzzy models is MatLab. In the Fuzzy Logic Toolbox of MatLab system, hybrid networks are implemented in the form of Adaptive Neuro-Fuzzy System (so-called ANFIS).

On the one hand, the ANFIS hybrid network is a single-output neural network with multiple inputs that make up fuzzy linguistic variables. The terms of the input linguistic variables are described by the standard membership functions for the MatLab system, and the terms of the output variable are represented by linear or constant membership functions.

Here is an algorithm for building a neuro-fuzzy network in this package. To do this, we will use the add-on Fuzzy Logic Toolbox, ANFIS Editor. To use the first on the command line, we call the function "fuzzy", to work in the editor - "anfisedit". This will bring up a dialog box.

Let's download the source data that will be used to build the network. Input parameters are selected factors (indicators), output parameter – selected result variable. We will construct neuro-fuzzy network on the example of data of corporates, with three input factor (X1-X3) which are different financial coefficients, and one output resulting variable (Y) which estimates the threat of bankruptcy of the corporation (its range is from 0 (very low threat of bankruptcy) to 1 (bankruptcy).

It should be noted, that the source data must be loaded in dat format. The graphical interface of the ANFIS editor after loading the training data is shown on Fig. 1.

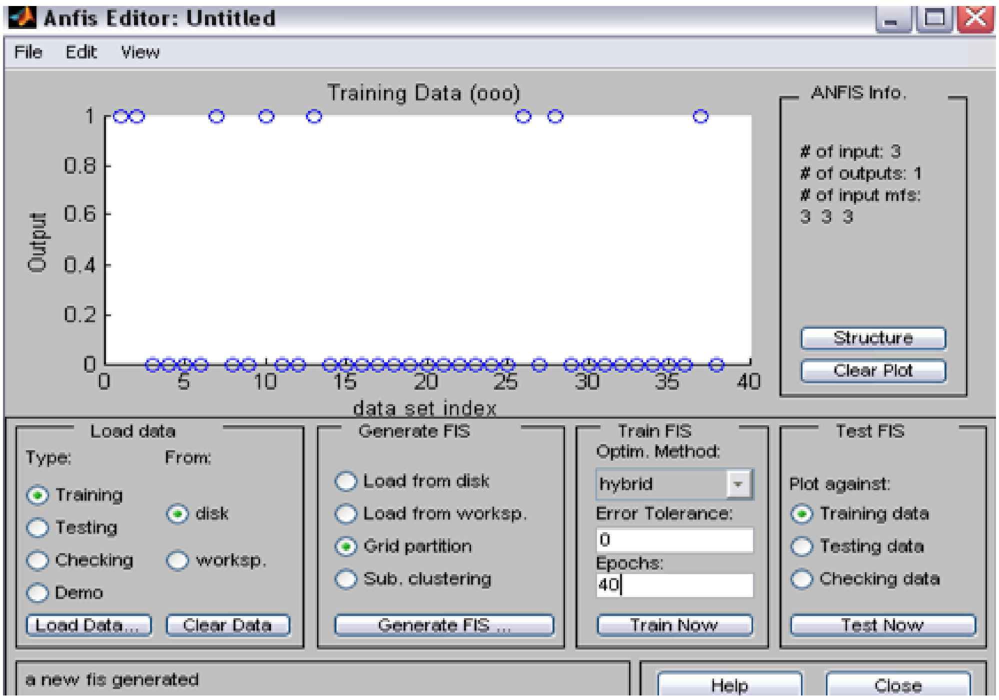

Fig. 1. Uploading data to the package MatLab

After the training data has been prepared and downloaded, it is possible to generate the structure of the Sugeno fuzzy FIS system, which is a model of the hybrid network in Matlab (“Generate FIS”). The first two options shown on the dialog window belong to the pre-created structure of the hybrid network and the last two – to the form of partitioning of the input variables of the model.

Before generating the structure of the Sugeno-type fuzzy output system, after the properties dialog box is called, we define for each of the input variables 3 linguistic terms, and choose the type of their membership function by the method of the least error [6]. In our model of bankruptcy risk estimation the smallest error was given by the triangular functions.

After generating FIS, a dialog box is displayed indicating the number and type of membership functions for the individual terms of the input variables and the output variable (Fig. 2).

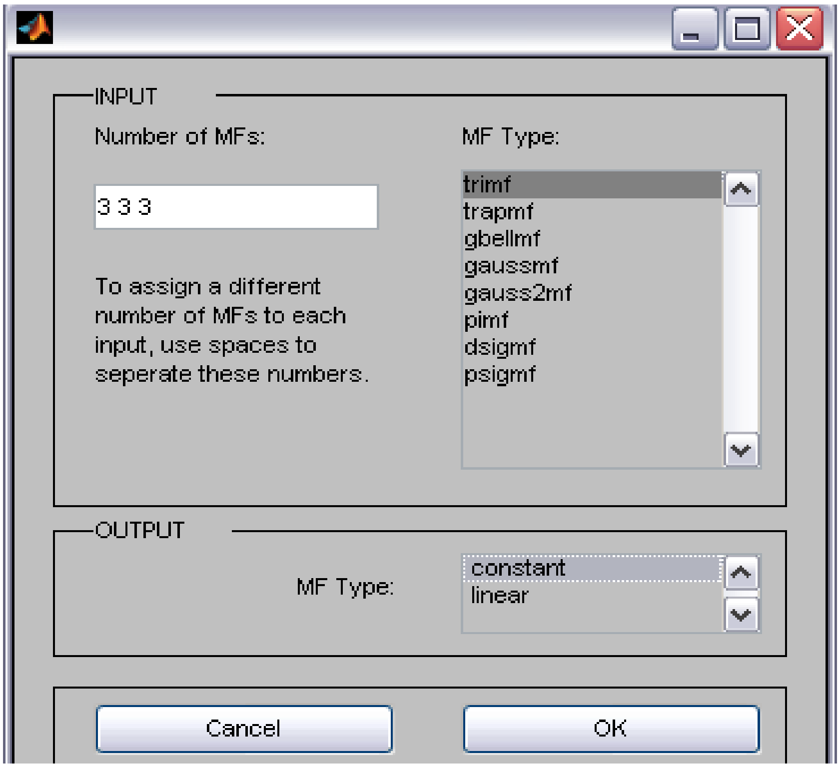

Fig. 2. Specification of the number and type of membership functions

After generating a hybrid network structure, it’s possible to visualize its structure (Fig. 3).

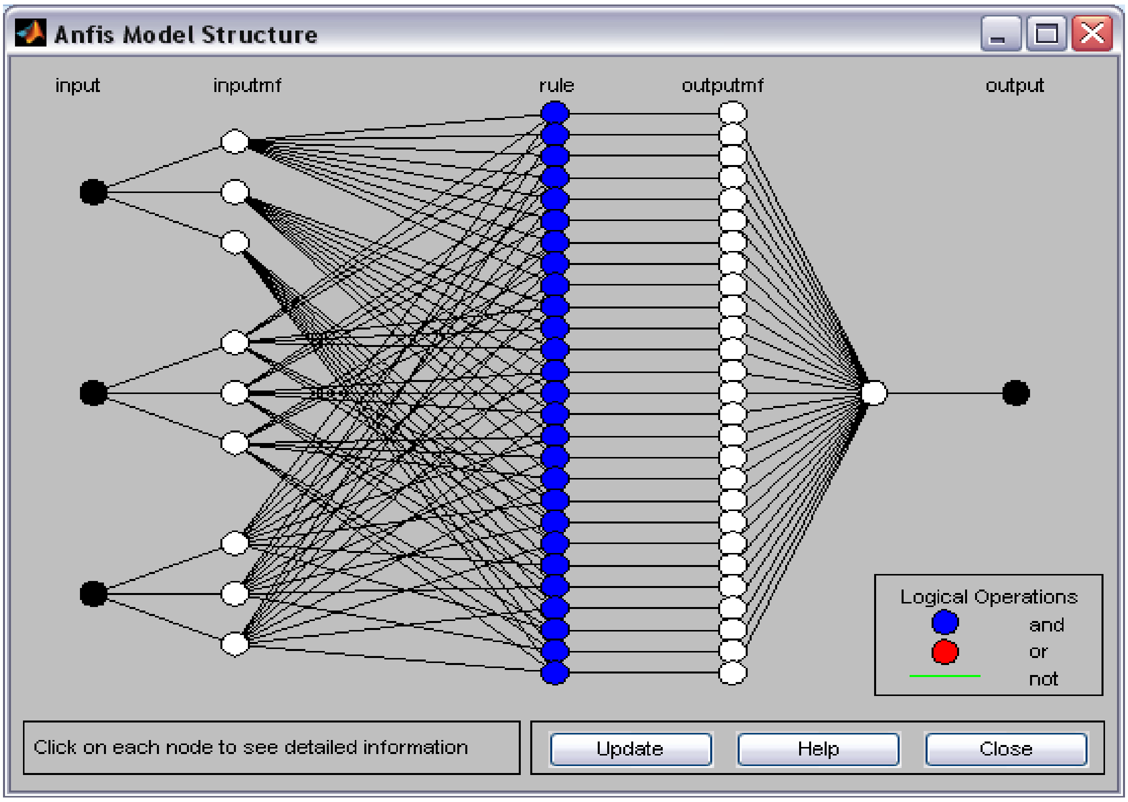

Fig. 3. Structure of the generated fuzzy output system

For the reviewed example (model of bankruptcy risk estimation), the fuzzy output system contains three input variables with three terms each, 27 fuzzy rules, one output variable with 27 terms.

Before starting the learning of a hybrid network, it is needed to specify training options, such as [2]:

1. To choose the method of training hybrid network: backpropo or hybrid, which is a combination of the method of least squares and the method of reducing the reverse gradient.

2. Set the Error Tolerance level to 0 by default (not recommended to change).

3. Set the number of training cycles (Epochs): the default value is 3 (it is recommended to increase it. For the current model its value was set as 40).

The progress of the training process is illustrated in the visualization window in the form of a graph of the error versus the number of training cycles (Fig. 4).

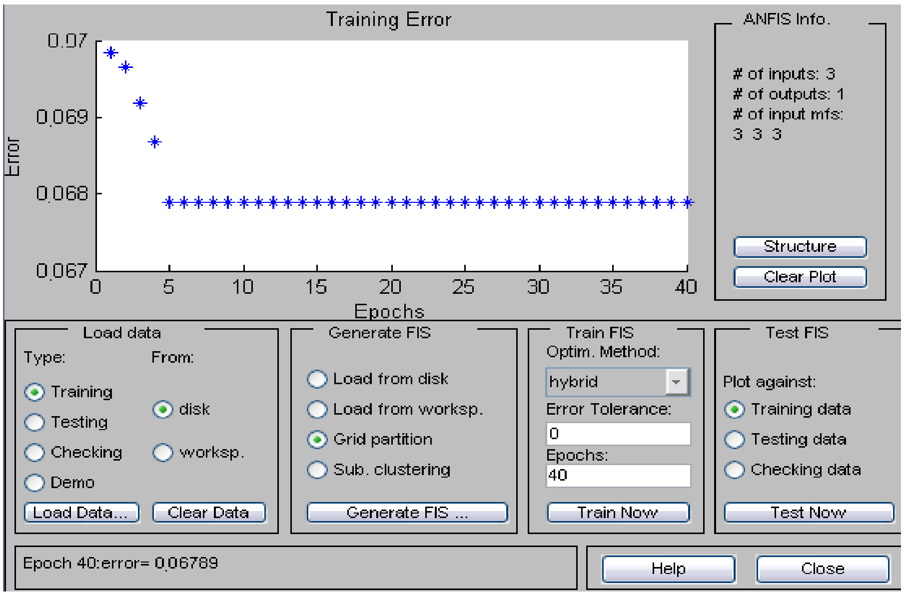

Fig. 4. The dependence of training errors on the number of learning cycles

A total of 40 training cycles were selected. The greater the number, the greater the value of the average error in the model, but also increase the adequacy of the model. As we can see from Fig. 4, the error values depend only on the first four training cycles, after which they all equal about 0.068. So, we can say about the high adequacy of the constructed neuro-fuzzy model.

A very important step is to test the built system. To do this, the package provides the appropriate function. The program will graphically show model errors.

Comparison of theoretical and empirical values is shown on Fig. 5.

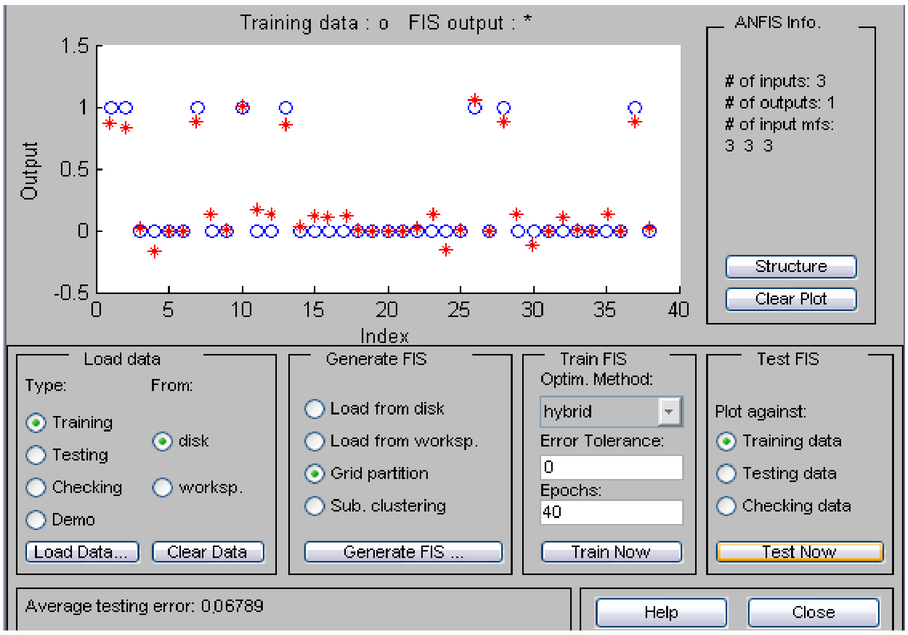

Fig. 5. Fuzzy neural system testing

As can be seen from Fig. 5, the neural network has adequately constructed the system. The average error in the test results is 6.789%. Therefore, the constructed model can and should be used in further research [3].

Further tuning of the parameters of the built and trained hybrid network can be performed using the standard graphical tools of the Fuzzy Logic Toolbox. For this purpose it is recommended to save the created system of fuzzy output in an external file with extension *.fis. FIS fuzzy output editor after uploading the saved file is shown on Fig. 6.

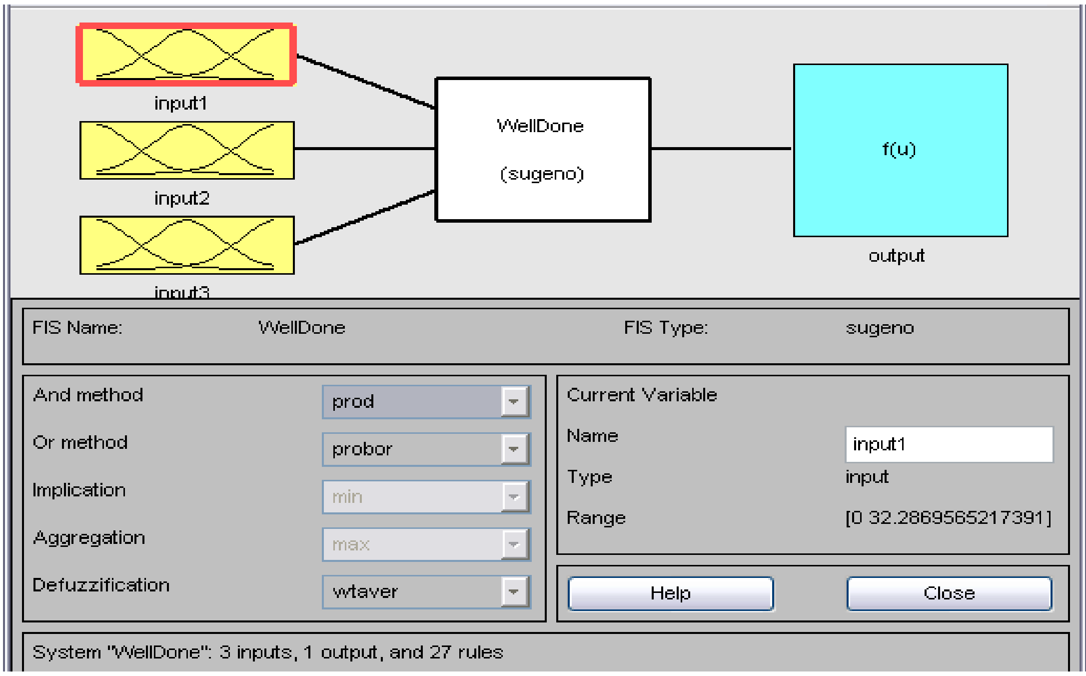

Fig. 6. FIS editor for generated fuzzy output system

The graphical interface of the editor functions of the built fuzzy output system is shown on figure 7.

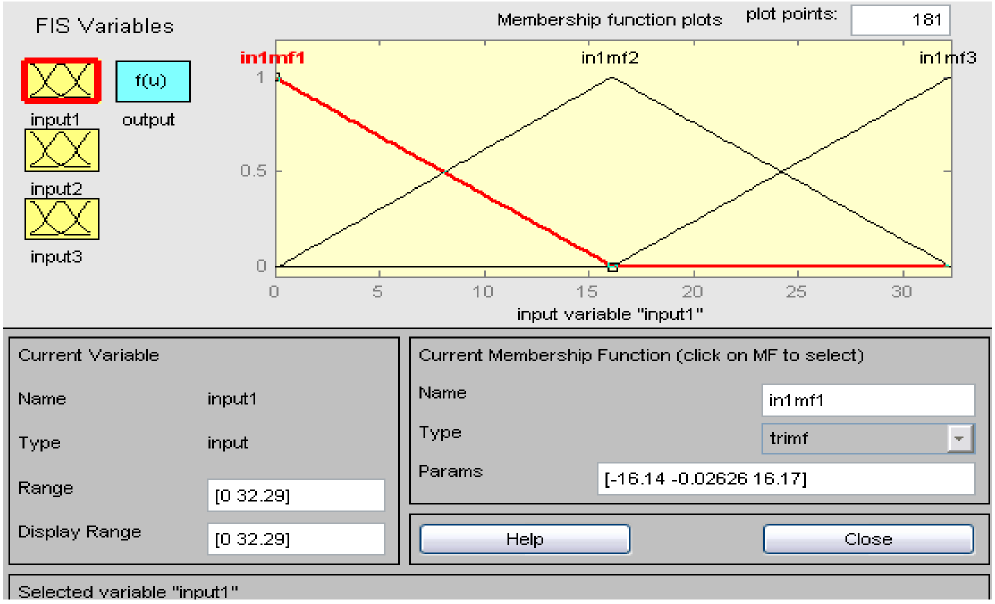

Fig. 7. Editor of membership functions

It should be noted that the model will be constructed with standard parameters of triangular membership functions, because for the case under study they are quite adequate [1, 9]. The fuzzy rules editor is shown on Fig. 8.

Fig. 8. Fragment of fuzzy rules base

As it’s been described above, the peculiarity of using MatLab for modelling with neural fuzzy networks is that the system automatically builds the rules. It is worth noting that all 27 of the existing rules are adequate and there is no need to edit them. So, they were remained in their original form.

The rules of the fuzzy system are shown on Fig. 9.

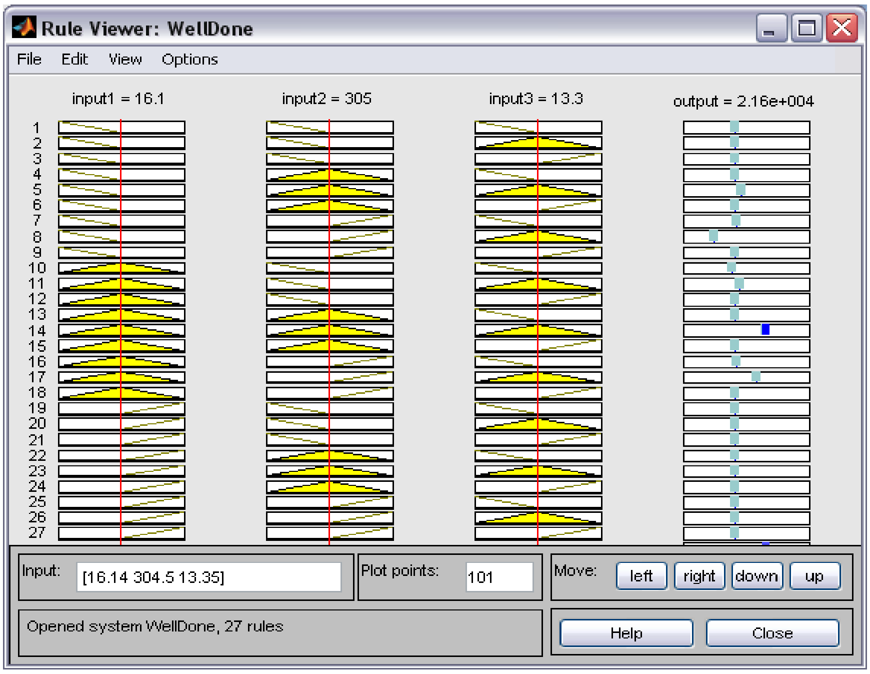

Fig. 9. Rules of built fuzzy system

So, now everything is ready to estimate the financial condition of enterprises. To solve this task, the "evalfis" function can be used. Let the values of the input parameters be equal:

X1 = 1,052;

X2 = 1,202;

X3 = 0,019.

Then the values of these indicators at the time of evaluation (vector x) and the use of forecasting functions are described in MatLab this way:

```
>> fuzzy
>> fis=readfis('WellDone.fis');
>> x=[1.052 1.202 0.019];
>> out=evalfis(x,fis)
```

The command “fuzzy” calls the Fuzzy Logic Toolbox add-on, which allows to set rules and other parameters (Fig. 6-9).

The “readfis” function selected a file from the working folder of MatLab, in which the system of fuzzy output was stored, i.e. the built neuro-fuzzy model.

The vector "x" is a vector of values of financial indicators of the enterprise.

“Evalfis is a function that determines the theoretical value of a resultant variable for a particular enterprise (research object). In our case, it indicates the threat of bankruptcy of enterprises. Thus, it was determined that the value of the resulting variable Y for the corporation under study is -0.541, i.e. the probability of bankruptcy for this enterprise is low in the near future [4].

Thus, fuzzy neural networks extend the scope of conventional neural networks because they allow fuzzy data to be operated. They are an extension of neural networks and apparatus of fuzzy logic. And despite the relatively low prevalence among researchers, this technique is already recognized as a modern, up-to-date, progressive one. One of the differences between neural networks and other methods is that neural network models are built on their own, based only on the information provided, that is, they do not require a pre-known model. In addition, this method takes into account the main disadvantages of other approaches, is adaptable to changing conditions, allows for a more flexible and quick response to the crisis. Therefore, it can be argued that the neural network tools can be effectively applied in many areas and, above all, in the economy.

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