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Durability prognostication of ferroconcrete structures on the basis of neural indistinct networks

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Abstract. The paper considers possible application of modern prognostication techniques as an element of a quality control system. Applied mathematical tools are the artificial indistinct neural networks with the inverse distribution of a TSK type architecture error. The analysis is made of the factors influencing the ferroconcrete durability. The selected input characteristics are: the sand fineness module, the number of of a lamellar and needle-shaped grains in crushed stone, cement volume weight, of a cement stone strength. The output parameter is the arithmetical mean value of the destroying force by the results of three experiments. The MS Access database was formed on the basis of the laboratory logbooks of the production input control. Two groups of tuples are formed: for training of indistinct neural network and for adequacy tests of the trained network. Mathematical model showed the efficiency of testing. The average error value was 9.6 kg/cm² or 2%.

1. Introduction

For more effective work of the «constant improvement» principle modern techniques of prognostication must be applied allowing the manufacturer to estimate in advance the efficiency of production at the stage of planning.

In the development of the quality control system at the enterprise the important element is the availability of data obtained as a result of control at the main stages of a production cycle.

An important stage of increase in the quality control is the creation of an electronic database which, in turn, would allow to use the saved-up empirical data for the analysis and prognostication [1].

2. Prognostication by means of the neural indistinct networks

The most popular are the artificial indistinct neural networks with the inverse error distribution [2, 3]. Presently the ANFIS and TSK architecture types of an indistinct neural net are of special interest. Such networks are universal approximators for the approximation of a dependence of an Y output signal on the input vector of $X = [x_1, x_2, \dots, x_N]^T$ where the expressions are used that were borrowed from the indistinct systems (in particular, the Mamdani-Zadeh and Takagi-Sugeno-Kanga's systems). It is theoretically proven that these expressions allow to approximate with any degree of accuracy any continuous nonlinear functions of multiple variables as the sum of functions (called by indistinct ones) by one variable [4].

In the Takagi-Sugeno-Kanga's network (hereafter abbreviated as TSK) the output signal is calculated with the expression:



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$$y(X) = \frac{\sum_{j=1}^M w_j y_j(X)}{\sum_{j=1}^M w_j}$$

where $y_j(X) = p_{i_0} + \sum_{j=1}^N p_{ij} x_j$ - is the i^{th} polynomial component of approximation,

w_i – the weight of the neural network components.

The values of components weight w_i are calculated by the formula given below (utilizing the rational form of the Gauss function)

$$w_i = \prod_{j=1}^N \mu_{ij}(x_j) = \prod_{j=1}^N \left(\frac{1}{1 + \left(\left(\frac{x_j - c_{ij}}{\sigma_{ij}} \right)^{2b_{ij}} \right)} \right).$$

These expressions correspond to the five-layer neural network have the block diagram shown in figure 1.

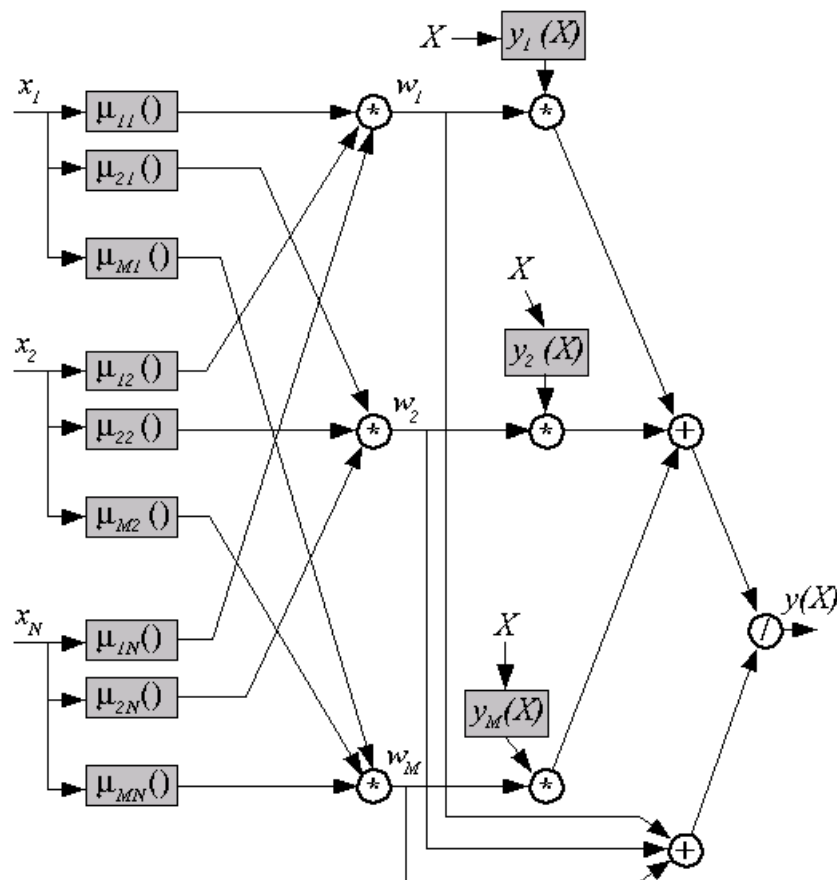


Figure 1. Block diagram of the TSK indistinct neural network.

For creation of the database registration on laboratory input control logbook of the enterprise for the production of railway reinforced concrete cross ties was used.

3. The analysis of the factors influencing the concrete durability

It is a well-known fact that concrete consists of cement, water and filler [5]. Each of these materials influences the resulting strength and other ferroconcrete parameters. The quantity and quality of each component are important for the formation of a solution with necessary characteristics. Let's analyze each component.

1. Filler. To obtain strong concrete it is necessary to select the filler material that will be able to provide the minimum quantity of emptiness (free space) between the grains. For example, if sand of one fraction is used, the amount of voids in a filler can be as high as 40% and if sand of different fractions (both the coarse-grained, and fine-grained sand in one solution) is used, the increased concrete density can be achieved. If granularity of a filler cannot be controlled (for example, sand with impurities, directly from a pit), the bigger amount of cement shall be required, and high durability is probable in all cases.

2. Water. For high-quality concrete only clear water without impurity is used. Salts, sulfates, fats and organic acids which are contained in water influence the process of concrete hardening and reduce the general durability of a ready solution. Therefore, to preparation a high-quality solution all water from river, ground, peat or industrial water must be replaced with drinking water. And moreover, sea water shall never be used.

3. Cement. The most important component which is the binder for all. The finer a clinker grinding, is the higher is the concrete brand, - and its binding ability, respectively. Another significant effect on concrete quality renders to the properties of a cement stone.

4. Coarse filler. The filler properties influence the tension at which the cracks formation is started under compression in the same degree, as well as the bending strength, and the relation between these two properties does not depend on the properties of filler. Except for high-strength concrete, the property of a filler, especially the structure of its surface, influence the resistance to compression much less than the tensile strength or threshold tension at compression.

Thus, considering the available laboratory input control data of the enterprise, the following characteristics of initial components may be offered for prognostication and control of concrete durability:

- Sand fineness module;
- Amount of lamellar and needle-shaped grains in crushed stone;
- Cement volume weight in the condensed state reflecting the grinding fineness;
- Compression resistance of cement stone.

The arithmetic-mean value of the destroying influence by the results of three experiments is used as an output parameter.

4. Development of the mathematical model based on the neural indistinct networks

Basing on the available data on the parameters of the initial components collected in 4 months and on the results of sample tests in the same period the MS Access database was created.

This database was used for calculations of the regularities connecting the parameters of initial components and the durability of samples prepared from them.

Two groups of tuples were created. The first group was used for training of indistinct neural network (the results are given in figure 2). The second group was used for check of the trained network on the adequacy (results are shown in figure 3) [6].

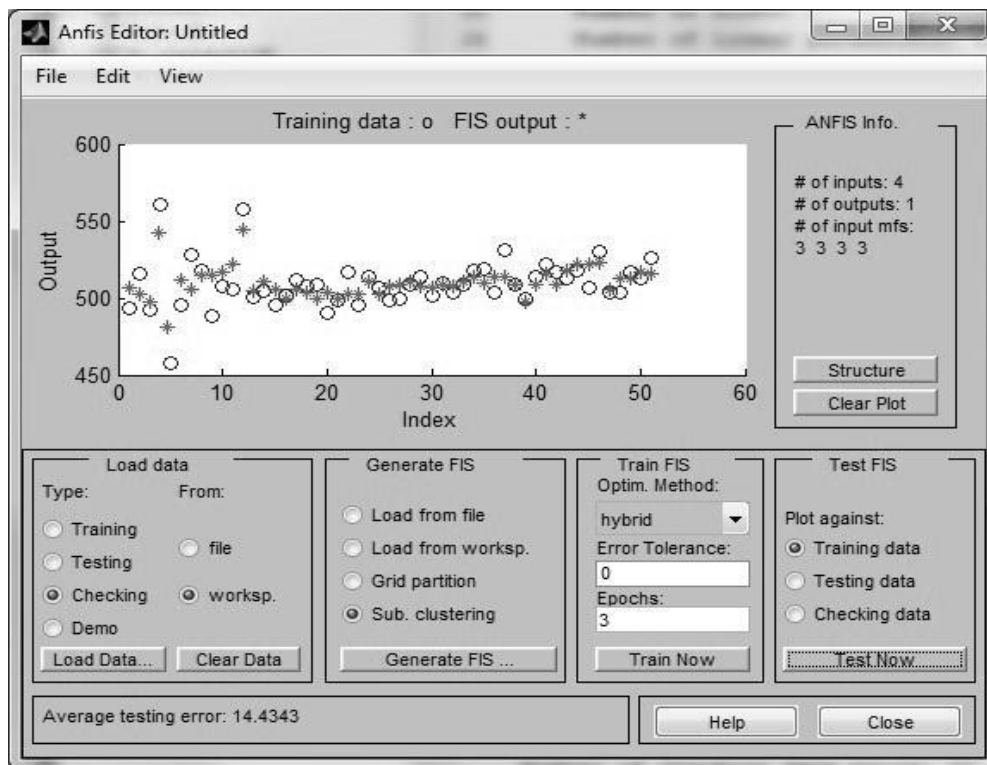


Figure 2. Neural network training results.

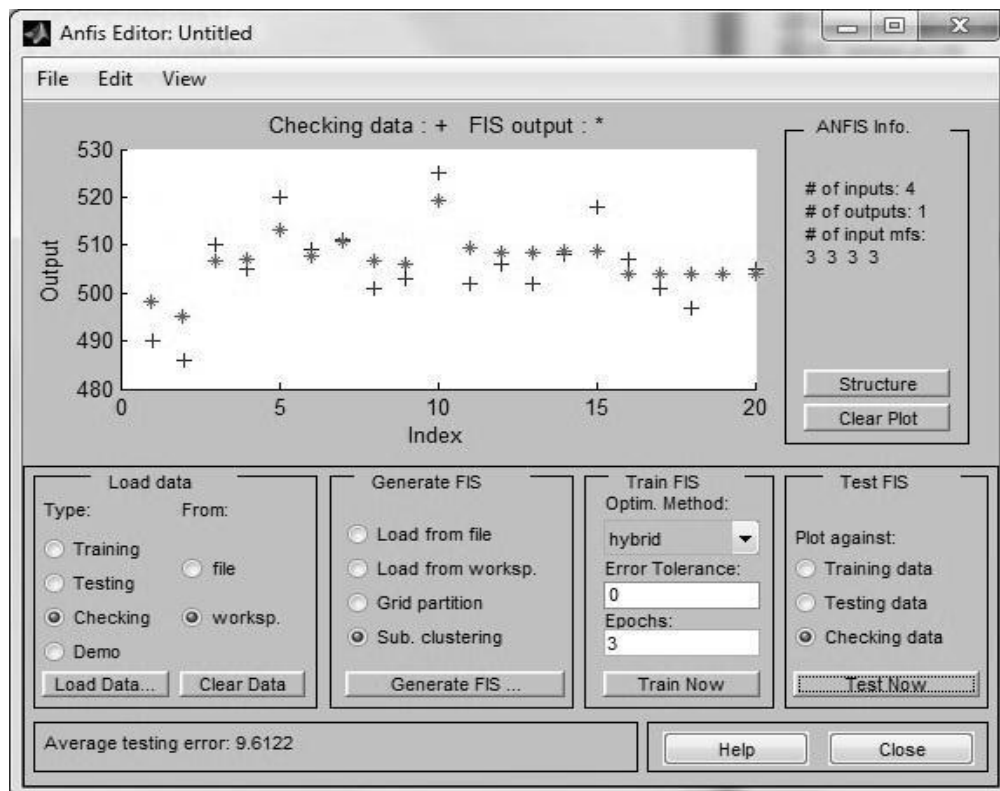


Figure 3. Neural network checking results.

The graphic interface of the user providing an access to the resources of network was developed for use of this indistinct neural network as a prognostication model and therefore, for the improvement of products quality.

The mathematical model showed the efficiency when testing. The average size of an error was 9.6 kg/cm² or 2%.

5. Conclusion

Information obtained by means of prognostication, based on mathematical modeling, allows to correct the process of production of concrete elements and structures at a stage of a concrete mix preparation and to obtain products with the stable preset characteristics of durability.

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