Crops reclamation management based on hybrid neuro-fuzzy systems

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Abstract. The article deals the technique of application of neuro-fuzzy systems in problems of management of melioration of agricultural crops is considered. In particular, an adaptive network based on the fuzzy inference system is developed, a method for predicting data flows based on the neuro-fuzzy network is proposed, which is implemented in the MATLAB ANFIS module.

1. Introduction

In the «Strategy of scientific and technological development of the Russian Federation», approved by the decree of the President of the Russian Federation dated December 1, 2016 № 642, it is noted that «in the next 10-15 years the priorities of scientific and technological development of the Russian Federation should be considered those areas that will allow to obtain scientific and technical results ... and provide ... the transition to a highly productive and environmentally friendly agro-and water management». Artificial neural networks allow us to solve problems that traditional methods cannot cope with. They are able to do this successfully, relying on incomplete, distorted information, i.e. not assuming any restrictions on the nature of the input data. Neural network modeling in its pure form is based only on data, without attracting any a priori considerations, which in turn has found wide application in the construction of predictive models of behavior of complex dynamic systems containing numerous time-varying parameters in interaction with different characteristics of the environment. Ins allow with any degree of accuracy to approximate an arbitrary continuous function, despite the absence or presence of periodicity or cyclicity, i.e. the network can be trained in such a way that it recognizes any set of data with high reliability and determines the further development of the studied process for a certain period. Since the time series of most indicators in agriculture are continuous functions, the use of Inslyapravleniyamelioratsiey agricultural crops is justified.

The first trainable artificial neural network perceptron - was proposed by F. Rosenblatt in 1958. However, after it was established in the 60s that the perceptron is not able to classify linearly inseparable classes of images, the field of research on neural networks has significantly narrowed [1]. Interest in neural networks increased markedly in the 80's after the discovery of new and powerful
learning algorithms (in particular, learning algorithm with back propagation of errors in various modifications) and new neural network architectures [2,3]. Currently, various industries and non-industrial sectors, including agricultural production, are showing increasing interest in artificial neural networks. Ins are effectively used for recognition of video images, Aero and photo images, in tasks of monitoring of agricultural lands and in many other spheres of agricultural production. Currently, a large number of commercial software modeling systems are known to allow the research and development of artificial neural networks for various applications, and a significant number of neurocomputer systems have been developed.

2. Materials and methods

A hybrid network based on a neuro-fuzzy system is a multilayer neural network of a special structure without feedbacks, which uses conventional (non-fuzzy) signals, weights and activation functions, and the execution of the summation operation is based on the use of a fixed T-norm, T-conorm or some other continuous operation. In this case, the values of inputs, outputs and weights of the hybrid neural network are real numbers from the segment [0, 1]. The basic idea behind the hybrid network model is to use an existing sample of data to determine the parameters of membership functions that best fit some fuzzy inference system. At the same time, well-known neural network training procedures are used to find the parameters of membership functions [2]. In the toolbox package of the MATLAB mathematical environment, hybrid networks are implemented in the form of the so-called adaptive neural fuzzy inference system ANFIS (Adaptive neuro-fuzzy inference system). On the one hand, the ANFIS hybrid network is a neural network with a single output and multiple inputs that represent fuzzy linguistic variables. In this case, the terms of the input linguistic variables are described by the standard Matlab membership functions, and the terms of the output variable are represented by a linear or constant membership function. On the other hand, the hybrid ANFIS network is a Sugeno-type zero or first order fuzzy inference A FIS system in which each of the fuzzy production rules has a constant weight equal to 1. In Matlab, the user has the ability to edit and configure ANFIS hybrid networks in a similar way to fuzzy inference systems, using all the tools of the Fuzzy Logic Toolbox package discussed earlier [3].

In the Toolbox package, Hybrid networks are implemented in the form of adaptive neuro-fuzzy inference systems ANFIS, the development and research of which is possible using two modes:

- in interactive mode using a special editor adaptive networks;
- in command line mode.

![Figure 1. Graphical interface of ANFIS editor.](image)
The ANFIS module allows you to create or load a specific model of an adaptive neuro-fuzzy inference system, train it, visualize its structure, modify and configure its parameters, and use a configured network to obtain fuzzy inference results. The initial step of working with the ANFIS module interface is to call the ANFIS-edit procedure from the command line (figure 1). The main menu of the ANFIS module is quite simple and is designed to work with a pre-created fuzzy output system.

The first step in creating a network is to load data (external file (disk) or workspace) using the Load Data procedure, which is a numeric matrix. The source data to be loaded can be of one of the following types:

- training data - mandatory data that is used to build a hybrid network;
- test data (Testing) - optional data that is used to test the built hybrid network in order to verify the quality of functioning of the built hybrid network;
- verification data (Checking) - optional data that is used to check the built hybrid network in order to find out the fact of retraining the network;
- demo data - allows you to download one of the hybrid network demos [4-6].

To begin with, using the m-file debugger editor, we will prepare training data that contains 105 lines of pairs «input variable value - output variable value» of the following form (figure 2). In this case, each data line corresponds to a separate point of the graph, which is represented by a circle for training data.

In our case, the original graph will be supplemented with 106 points of verification data, each line of which also corresponds to a separate point of the graph, represented by a plus.

![Figure 2. Training data building an ANFIS hybrid network.](image)

After preparing and loading the training data, you can generate the structure of a Sugeno-type fuzzy inference ANFIS system, which is a type of hybrid networks in the Matlab environment, which can be implemented using the generate AFIS procedure. In the process of designing the structure of a new ANFIS, it is possible to independently split all input variables into their value regions or use the subtractive clustering procedure to pre-partition the values of input variables into clusters of close values [7-9].

The implementation of the generate FIS-procedure calls a dialog box specifying the type of membership functions for the individual terms of the input variable and the output variable. In this case, you can choose any type of membership functions implemented in the Matlab system. After generating the hybrid network structure, you can visualize its structure by executing the Structure procedure. The structure of the resulting FIS fuzzy inference system is displayed in a separate window.
and is quite trivial in appearance (figure 3). For this example, the fuzzy output system contains one input variable with 4 terms, 4 fuzzy production rules, one output variable with 4 terms. The components of the ANFIS system are represented by nodes of the corresponding color.

![Figure 3. Structure of the generated fuzzy inference system.](image)

The further algorithm of training and setting parameters consists of the following stages:

- choice of hybrid network learning method (reverse propagation or hybrid);
- assessment of learning error level;
- set the number of training cycles.

The Train Now tool is used to train the network. In this case, the progress of the learning process is illustrated in the visualization window in the form of a graph of the error dependence on the number of training cycles. Similarly, additional stages of neural network testing and validation can be implemented, with pre-loaded training data.

![Figure 4. Graphical interface for viewing the rules of the generated fuzzy inference system.](image)
In addition, you can perform a visual analysis of the output surface for the built hybrid network, which also allows you to estimate the values of the output variable. You can analyze a trained and configured hybrid network by visualizing the fuzzy inference surface. For this purpose, you should use the fuzzy output system surface viewer (figure 4). To obtain the value of the output variable of interest, you must specify a specific value of the input variable, similar to the General recommendations of fuzzy inference systems. In this case, the graph of functions belonging to the output variable will indicate the desired value of the output variable.

3. Conclusion
As a result of research of a problem of management of melioration of agricultural crops on the basis of systems of neuro-fuzzy conclusion the following results are received:

- methods and approaches of development of neuro-fuzzy inference systems are considered;
- possibilities of application of computer systems for realization of algorithm by a neural network are analyzed;
- the software implementation of the proposed approach in the mathematical system Matlab using module ANFIS.

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