Comparison of the neural net training algorithms for the emergencies forecasting of technological processes

S A Tkalich, V L Burkovsky and O Ja Kravets
Voronezh State Technical University, 14, Moscow ave, Voronezh, Russian Federation

E-mail: csit@bk.ru

Abstract. Composite model of emergencies forecasting of technological process of chemical water purification for the nuclear power plant (NPP) is considered. To create a neural network component of this model the Neural Networks Toolbox MATLAB package is used. In the process of neural net training the gradient of error functionality in three controlled parameters is calculated: viz., specific electric conductivity, hydrogen indicator pH, concentration of silicon acid. A comparison was made of a training algorithm of CGF realizing Fletcher–Reeves method with LM algorithm of Levenberg–Markvardt. The conclusion is drawn that a sufficiently exact repetition of a type of initial function of the proximity degree to an emergency occurs when the LM algorithm is used.

1. Introduction
The choice of the criterion identifying the condition of technological process as an emergency, cannot be proven with guarantee in most cases with sufficient degree of probability [1]. The criterion uniting in itself three components of a composite model of forecasting is the composite integrated criterion [2]. Each component of the this forecasting system is characterized by its own indicator: for thermodynamic model it is the indicator of persistence H which changes from 0 to 1; for the productional model it will be a measure of proximity to an emergency situation L (which accepts values from 0 to 1); and for neural network model it is certainly the function of degree of proximity to an accident of N (which changes from 0 to 1 too).

2. Analysis of problem
It is obvious that the reaction of an accident-free management system to an emergence of critical condition is extremely fast response to the critical parameter revealed by the diagnostic and forecasting means [3, 4] for the purpose of its reduction to nominal limits, on the condition of sufficiency of the reserve which is available for this stock of time and the time of this reduction of $t_{\text{priv}}$ defining the speed of the corresponding control path (the control). Thus it follows that a certain functionality representing the superposition of indicators of each model [5] can be offered as the required criterion of a state, i.e.

$$S=F(H, L, N, t_{\text{reserve}}, t_{\text{priv}}),$$

this criterion considering simultaneously both the current values of the functional indicators of the process defining the reserve time $t_{\text{reserve}}$ and the available speed of $t_{\text{priv}}$ of a control system. Such
functionality is integrated, in the specified sense, within the concept of an accident-free management [6].

When developing the neural network components of the composite emergencies forecasting model, the choice of a method of training of a neuronet is the most important.

When training a neuronet, the functionality characterizing the quality of training is calculated as:

\[ J = \frac{1}{2} \sum_{i=1}^{M} \sum_{q=1}^{Q} (t^{q} - a^{q}_{i})^{2}, \]

where \( J \) - functionality; \( Q \) - volume of selection; \( M \) - number of network layers; \( q \) - the selection number; \( S^{M} \) - number of neurons in the output layer; \( a^{q} = [a^{q}_{i}]M \) - a signal vector at the network output; \( t^{q} = [t^{q}_{i}] \) - a vector of desirable (target) values of a signal at the output of the network for the selection numbered as \( q \).

Then, by means of either training method, the values of the configured settings of a network (scales and shifts) which provide the minimum value of error functionality shall be defined. The majority of training methods are based on the calculation of a gradient of error functionality in the configured settings.

3. Composite emergencies forecasting model

As an example we shall consider the composite emergencies forecasting model of the technological process of chemical water purification (CWP) for a nuclear power plant (NPP) [7].

The key controlled parameters of CWP process are specified in table 1.

| Indicators                                      | Value          |
|------------------------------------------------|----------------|
| Specific electric conductivity, maximum        | 1.2 µS/cm      |
| Hydrogen indicator pH (in pH units)            | 5.6-8.0        |
| Silicon acid concentration, maximum            | 20 µg/dm³      |

The fragment of the training selection is given in figure 1. It corresponds to a normal functioning of CWP process.

![Figure 1](image_url)
Nominal rates of parameters are equal to: $Y_{1\text{nominal}}$ (the specific electric conductivity) = $1,2 \ \mu$S/cm, $Y_{2\text{nominal}}$ (pH) = 7,0 units pH, $Y_{3\text{nominal}}$ (silicon acid concentration) = $14 \ \mu$g/dm$^3$, respectively.

For the creation of a network we use the Neural Networks Toolbox MATLAB [8] package.

The Neural Networks Toolbox package (NNT) MATLAB contains the tools for design, modeling, training and use of a set of the known artificial neural networks (ANN): from basic models of a perceptron to the most modern associative and self-organized networks [9, 10].

At the beginning, the training values of the maximum quantity of training cycles (hereinafter – the epochs – i.e., the maximum quantity of cycles (eras) of training) and the minimum value of an error functionality training are set (the goal – is the extreme value of a training criterion). There is an initialization of initial values of scales and shifts. If the value of error functionality reaches the minimum value or it is equal to zero, or the quantity of cycles of training is equal to zero, then the program exits the cycle of network training of and proceeds to the training test.

The essence of a test procedure is the new analyzed data, other than those which were used when training network is applied to the input of the already trained network. At the output of this network we obtain the function of the emergency proximity degree for the new input data. Let's combine the initial function of the proximity degree to an accident and the function of the proximity degree realized by means of neural network in the same diagram (figure 2).

![Figure 2](image-url)  
**Figure 2.** Comparison of two functions of the proximity degree to an emergency.

![Figure 3](image-url)  
**Figure 3.** Error functionality in the process of training for CGP algorithm.
4. Comparison of two training algorithms

Let's compare two training algorithms: CGF algorithm realizing the Fletcher-Reeves method and thean LM algorithm of Levenberg–Markvardt.

The type of error functionality in the course of training for the CGF algorithm is shown in figure 3, and for the LM algorithm - in figure 4.

![Graph showing error functionality in the process of training for LM algorithm.]

**Figure 4.** Error functionality in the process of training for LM algorithm.

Conclusion

It is obvious that the neural network is trained rather qualitatively. It is also obvious that a sufficiently exact repetition of the initial function type of the emergency proximity degree occurs when the LM algorithm is used.

References

[1] Fox J 2003 Probability, logic and the cognitive foundations of rational belief. Journal of Applied Logic 1(3-4) 197-224

[2] Zhigang S, Long Z, Lei C and Yingdong S 2013 Research on failure criterion of composite based on unified macro- and micro-mechanical model Chinese Journal of Aeronautics 26(1) 122-9

[3] Daliento S, Chouder A, Guerriero P, Massi A, Mellit A, Moeini R and Tricoli P 2017 Monitoring, Diagnosis, and Power Forecasting for Photovoltaic Fields: A Review International Journal of Photoenergy 2017 1356851

[4] Romansky R and Noninska I 2016 Architecture of Combined e-Learning Environment and Investigation of Secure Access and Privacy Protection International Journal of Human Capital and Information Technology Professionals (IJHCITP) 3(7) 89-106

[5] Xu P and Ji Y 2014 Load Superposition and Shifting Method with Simulation tools for Energy Planning and the Case Analysis Energy Procedia 61 730–4

[6] Niemi P 2017 Prevention of free-time accidents is part of responsible employer activity Available from: https://www.upm.com/news-and-stories/articles/2017/04/prevention-of-free-time-accidents-is-part-of-responsible-employer-activity/

[7] Zakrzewska-Kołtuniewicz G 2017 Water management in nuclear power plant using advanced
low-temperature systems *European Water* **58** 345-50

[8] Deep Learning Toolbox. Create, analyze, and train deep learning networks Available from: https://www.mathworks.com/products/deep-learning.html

[9] Kohonen T 1989 Self-Organizing and Associative Memory *Applied Optics* **8**(1) doi: 10.1007/978-3-642-88163-3

[10] Shen F, Kasai W and Hasegawa O 2012 A General Associative Memory Based on Self-organizing Incremental Neural Network *Neurocomputing* **104** doi: 10.1016/j.neucom.2012.10.003