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INTELLIGENT COMPUTER NETWORK FOR RAILWAY TRANSPORT USING NEURAL NETWORK FOR DETERMINING THE OPTIMAL ROUTE

ІНТЕЛЕКТУАЛЬНА КОМП'ЮТЕРНА МЕРЕЖА ЗАЛІЗНИЧНОГО ТРАНСПОРТУ З ВИКОРИСТАННЯМ НЕЙРОМЕРЕЖНОГО ЗАСОБУ ДЛЯ ВИЗНАЧЕННЯ ОПТИМАЛЬНОГО МАРШРУТУ

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Abstract. *At the present stage, the information and telecommunications system of railway transport uses local area networks of Ethernet family technologies and the OSPF protocol, when used in real time, a problem arises due to constant changes in the volume of transmitted data, and for its solution it is advisable to use a neural network tool, which confirms the relevance of the topic. As a mathematical apparatus for solving the problem of determining the optimal route, a neural network of the configuration «56-1-X-56» was taken, where 56 (first position) is the number of input neurons (delays on routers); 1 is the number of hidden layers; X is the number of hidden neurons that require additional research; 56 (last position) is the number of output neurons (signs of the entry of computer network channels into the route). In the program mode of the Deep Learning Toolbox package of the MatLAB environment, a corresponding model "Delay_path" was created, on which the root mean square error and the number of epochs of training of neural networks with different numbers of hidden neurons were studied using different neuron activation functions according to different learning algorithms on samples of different lengths. It was determined that the accuracy of the created neural network tool is 70 % for the considered fragment of the information and telecommunications system of railway transport.*

Keywords*: information and telecommunications system, Ethernet family technologies, OSPF protocol, delay on routers, neural network tool, activation function, training algorithm, mean square error, epoch, accuracy.*

Introduction

Problem statement. Today, the railway transport of Ukraine has implemented an information and telecommunications system (ITS), the basis of which is computer networks of the Ethernet family (Ethernet, Fast Ethernet, Gigabit Ethernet) [3]. The main issue in the functioning of computer networks of railway transport is the organization of routing, which is achieved at the present stage using the well-known

OSPF (Open Shortest Path First) protocol, which is based on the principle of finding the shortest path. But such a routing protocol is not able to work in conditions of sharp changes in the intensity of traffic flows, as well as changes in the network configuration and taking into account several metrics for determining the optimal path. In this regard, there is a need to use other approaches to routing in computer networks of railway transport, in particular the use of neural network technologies.

Analysis of recent research. A review of scientific sources showed that for routing in computer networks it is possible to use: Hopfield network [1]; multilayer perceptron [6]; neural fuzzy network [7]; ant method [4]; GWO method [5], as well as connecting a neural network with a genetic algorithm [2]. For example, in [6] the authors determined the optimal route in the computer network of the ITS of railway transport on the software model of the multilayer perceptron «34-2-X-34», where the channel throughput was taken as the metric. But in some cases, to determine the optimal route in a computer network, it is advisable to use completely different metrics, in particular, delays on routers.

The purpose of the article is to study the intelligent computer network of railway transport using the created neural network tool to determine the optimal route. In accordance with the goal, the following tasks are set: 1) to create a neural network tool to determine the optimal route in the computer network of railway transport; 2) to determine the optimal parameters of the created neural network tool; 3) to assess the accuracy of determining the optimal route for the considered fragment of the ITS of railway transport based on the use of the created neural network tool.

1. Problem statement. Figure 1 shows the general structure of the computer network for the considered fragment of the railway transport ITS [7]. The computer network can be represented as an undirected graph G(V,W), where V is the vertices of the graph (a set of routers, M=48), and W is the edges of the graph (a set of channels connecting routers N=56). The delay on the router, μs, is taken as the weight of the edges.

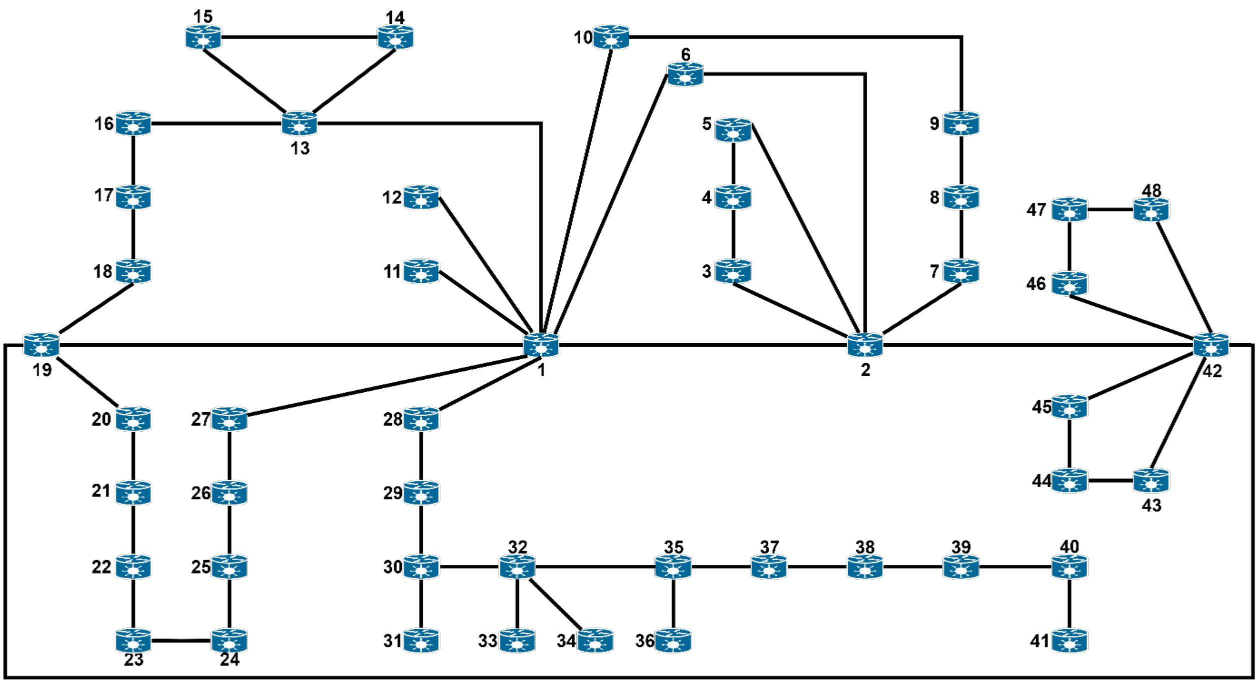

Figure 1 – General structure of the ITS computer network [7]

The optimization criterion is the minimum sum of delays on routers that make up the route in a computer network:

$$\sum_{i=1}^{M}\sum_{j=1}^{N} t_{ij}\cdot p_{ij} \rightarrow min,$$

where t_{ij} – delay between the i-th and j-th routers;

p_{ij} – sign of the entry of the (i-j) network channel into the route, and p_{ij}=1 if the (i-j) channel enters the route; p_{ij}=0 if the (i-j) channel does not enter the route.

2. Mathematical apparatus. As the main method for solving the problem, a multilayer perceptron (MLP) of the configuration «56-1-X-56» was taken, where 56 (first position) is the number of input neurons (delays on routers); 1 is the number of hidden layers; X is the number of hidden neurons that require additional research; 56 (last position) is the number of resulting neurons (signs of computer network channels entering the route) and is shown in Figure 2.

3. Sample Preparation. Suppose we need to determine the optimal route between two routers: «23» and «5»; to do this, we consider all possible routes.

Route_1: [23, 24, 25, 26, 27, 1, 2, 5];

route_ 2: [23, 24, 25, 26, 27, 1, 2, 3, 4, 5];

route_3: [23, 24, 25, 26, 27, 1, 6, 2, 5];

route_4: [23, 24, 25, 26, 27, 1, 6, 2, 3, 4, 5];

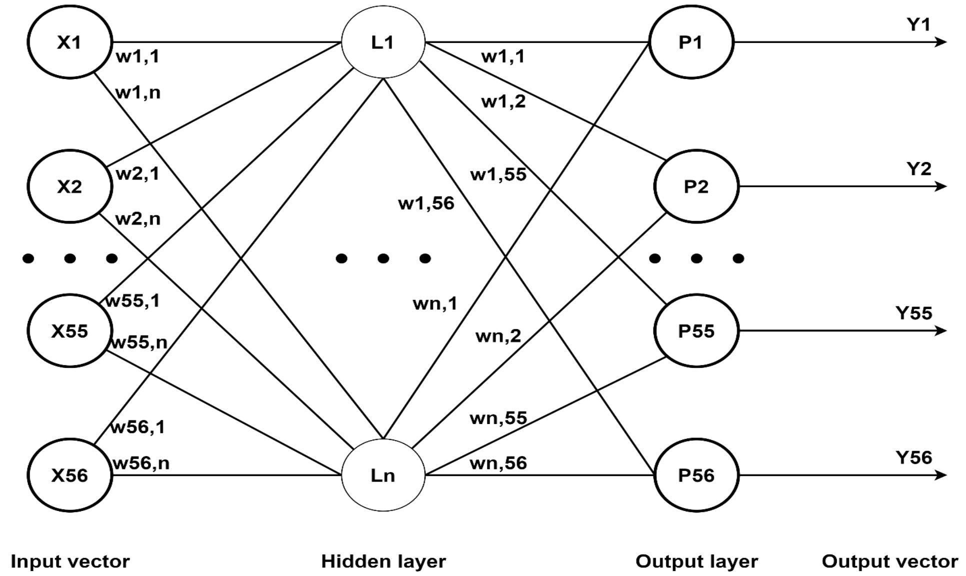

Figure 2 – Structure of the multilayer perceptron «56-1-X-56»

route_5: [23, 24, 25, 26, 27, 1, 10, 9, 8, 7, 2, 5];

route_6: [23, 24, 25, 26, 27, 1, 10, 9, 8, 7, 2, 3, 4, 5];

route_7: [23, 22, 21, 20, 19, 1, 2, 5];

route_8: [23, 22, 21, 20, 19, 1, 2, 3, 4, 5];

route_9: [23, 22, 21, 20, 19, 1, 6, 2, 5];

route_10: [23, 22, 21, 20, 19, 1, 6, 2, 3, 4, 5];

route_11: [23, 22, 21, 20, 19, 1, 10, 9, 8, 7, 2, 5];

route_12: [23, 22, 21, 20, 19, 1, 10, 9, 8, 7, 2, 3, 4, 5];

route_13: [23, 22, 21, 20, 19, 18, 17, 16, 13, 1, 2, 5];

route_14: [23, 22, 21, 20, 19, 18, 17, 16, 13, 1, 2, 3, 4, 5];

route_15: [23, 22, 21, 20, 19, 18, 17, 16, 13, 1, 6, 2, 5];

route_16: [23, 22, 21, 20, 19, 18, 17, 16, 13, 1, 6, 2, 3, 4, 5];

route_17: [23, 22, 21, 20, 19, 18, 17, 16, 13, 1, 10, 9, 8, 7, 2, 5];

route_18: [23, 22, 21, 20, 19, 18, 17, 16, 13, 1, 10, 9, 8, 7, 2, 3, 4, 5];

route_19: [23, 22, 21, 20, 19, 42, 2, 5];

route_ 20: [23, 22, 21, 20, 19, 42, 2, 3, 4, 5];

route_21: [23, 24, 25, 26, 27, 1, 19, 42, 2, 5];

route_22: [23, 24, 25, 26, 27, 1, 19, 42, 2, 3, 4, 5].

Thus, the total sample consists of 440 examples (20 examples for each of the 22 cases of routing between given nodes): for MLP training – 70%; for MLP testing – 15%; for MLP validation – 15%.

4. Creation of a neural network tool. In the program mode of the Deep Learning Toolbox package of the MatLAB environment, a multilayer perceptron was created (Figure 3), the structure of which coincides with the proposed configuration of the neural network (see Figure 2).

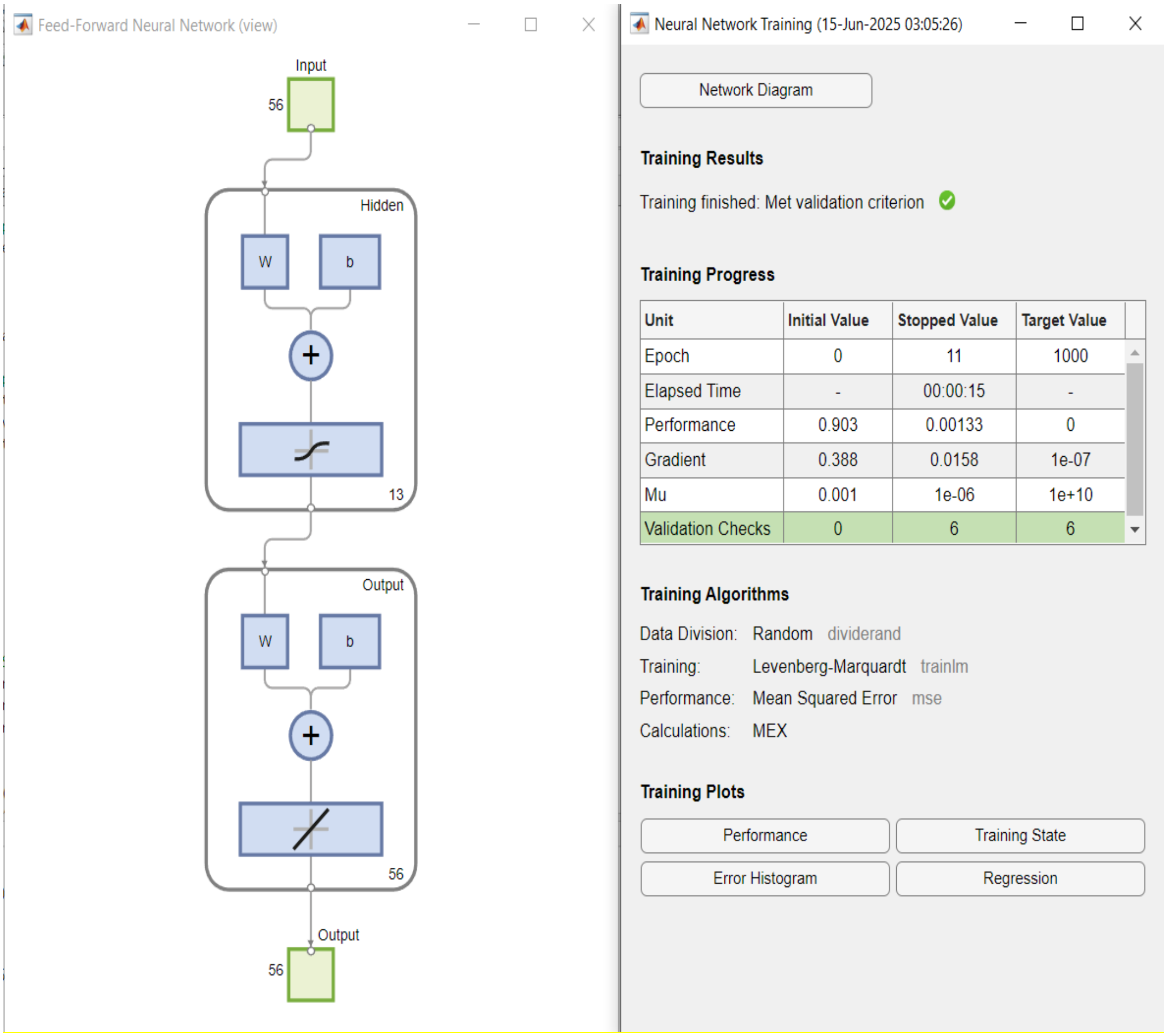

Figure 3 – Structure of a neural network created in MatLAB

5. Determination of optimal parameters of the created neural network tool. On the created software model «Delay_path», studies were conducted on the mean square error and the number of epochs of neural networks with different activation functions of hidden neurons: hyperbolic tangent; sigmoidal function; linear function with different numbers of hidden neurons (13, 30 and 50) using different training methods (Levenberg-Marquardt, Bayesian regularization, Conjugate gradient method) on samples of different lengths (66, 220 and 440 examples), which allowed us to determine the optimal parameters of the neural network: number of hidden neurons – 30; activation function of hidden neurons – hyperbolic tangent; training algorithm – Levenberg-Marquardt algorithm; sample length – 440 examples.

6. Assessment of the accuracy of determining the optimal route for the considered fragment of the railway ITS based on the use of the created neural network tool. 10 experiments were conducted, according to the results of which the coincidence of the determined route on the software model «Delay_path» with the optimal route determined by the Dijkstra algorithm was 7. As an example of coincidence, the result obtained is presented in Figure 4. The software model «Delay_path» determined the route, which includes the following edges: 23-24; 24-25; 25-26; 26-27; 27-1; 1-2; 2-5, which coincides with the optimal route for given values of delays on routers (see Figure 4).

Conclusions

1) To determine the optimal route in the computer network of the considered fragment of the railway transport ITS, a neural network tool was taken, namely a neural network of the configuration «56-1-X-56», where 56 (first position) is the number of input neurons (delays on routers); 1 is the number of hidden layers; X is the number of hidden neurons that require additional research; 56 (last position) is the number of resulting neurons (signs of the computer network channel entering the route).

2) In the program mode of the Deep Learning Toolbox package of the MatLAB environment, the «Delay_path» model was created, the studies on which provided the opportunity to determine the optimal parameters of the neural network: the number of hidden neurons is 30; the activation function of the hidden neurons is hyperbolic tangent; the learning algorithm is the Levenberg-Marquardt algorithm.

3) The accuracy of determining the optimal route in the computer network of the considered fragment of the railway transport ITS based on the use of the created neural network tool was 70 %.

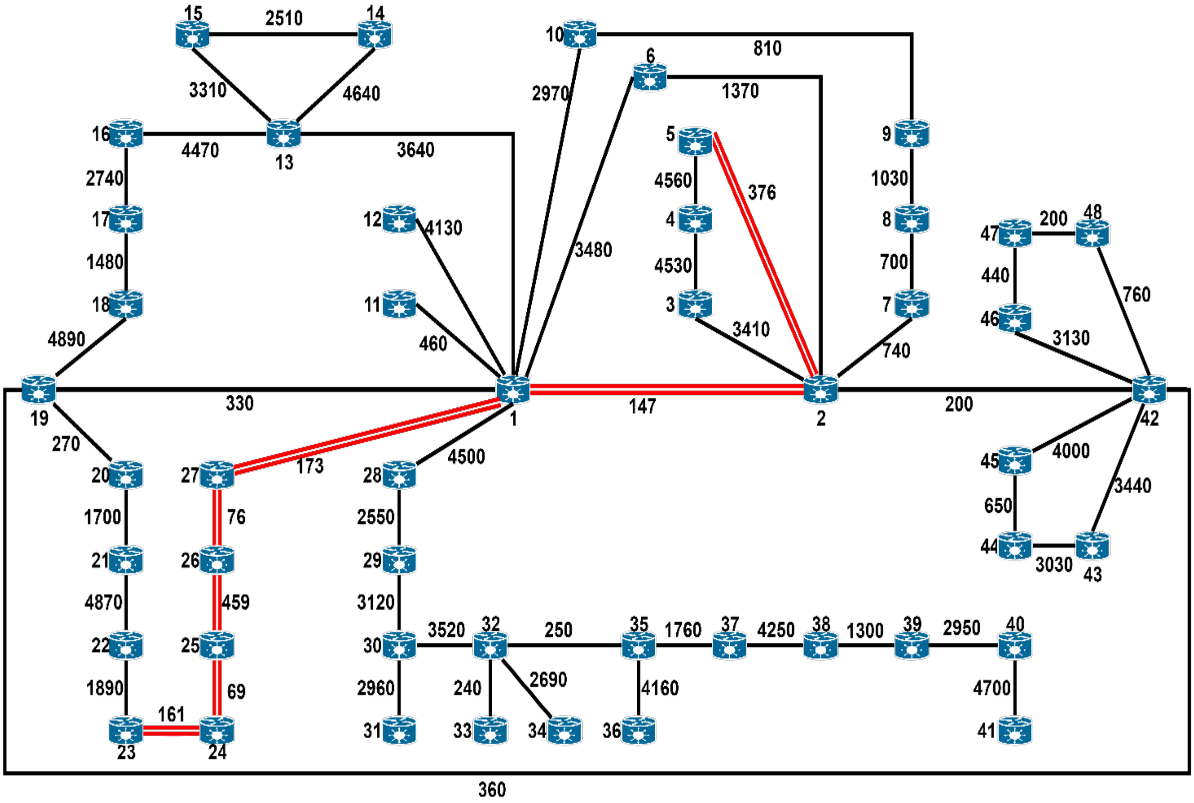

Figure 4 – Defined path on the created model «Delay_path»

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Анотація. *На сучасному етапі в інформаційно-телекомунікаційній системі залізничного транспорту застосовуються локальні мережі технологій родини Ethernet і протокол OSPF, при використанні якого в реальному часі з'являється проблема завдяки постійним змінам обсягів передаваємих даних, і для вирішення якої доцільно використання нейромережного засобу, що підтверджує актуальність теми. У якості математичного апарату для розв'язання задачі визначення оптимального маршруту взято нейронну мережу конфігурації «56-1-X-56», де 56 (перша позиція) – кількість вхідних (input) нейронів (затримки на маршрутизаторах); 1 – кількість прихованих шарів; X – кількість прихованих нейронів, що потребує додаткового дослідження; 56 (остання позиція) – кількість вихідних (output) нейронів (ознаки входження каналів комп'ютерної мережі до маршруту). У роботі в програмному режимі пакета Deep Learning Toolbox середовища MatLAB створено відповідну модель «Delay_path», на якій проведено дослідження середньоквадратичної похибки та кількості епох навчання нейронних мереж з різною кількістю прихованих нейронів при використанні різних функцій активацій нейронів за різними алгоритмами навчання на вибірках різної довжини. Визначено, що точність створеного нейромережного засобу складає 70 % для розглянутого фрагменту інформаційно-телекомунікаційної системи залізничного транспорту.*

Ключові слова: *інформаційно-телекомунікаційна система, технології родини Ethernet, протокол OSPF, затримка на маршрутизаторах, нейромережний засіб, функція активації, алгоритм навчання, середньоквадратична похибка, епоха, точність.*