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INTELLIGENT COMPUTER NETWORK FOR RAILWAY TRANSPORT USING NEURO-FUZZY MEANS FOR DETERMINING THE OPTIMAL ROUTE

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

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Abstract. *At the present stage, the information and telecommunications system of railway transport uses local networks of the following technologies: Ethernet; Fast Ethernet; Gigabit Ethernet, as well as the OSPF routing 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 possible to consider the use of a neurofuzzy tool, which confirms the relevance of the topic. As a mathematical apparatus for solving the problem of determining the optimal route, a neural fuzzy network of the configuration «12-24-144-144-1» was taken, where 12 is the number of input neurons (delays on routers); 24 is the number of hidden neurons taking into account the terms; 144 is the number of hidden neurons according to the number of rules; 1 is the number of resulting neurons (total delay on routers along the route). Using the Fuzzy Logic Toolbox package of the MatLAB environment, a Sugeno ANFIS algorithm (with a Gaussian membership function for hidden neurons) was created, on which the mean square error and the number of learning epochs were studied using various learning optimization methods (Backpropagation, Hybrid) on samples of different lengths. It was determined that the accuracy of the created neurofuzzy tool is 80% for the considered fragment of the railway transport information and telecommunications system; a general scheme of an intelligent computer network based on ANFIS was proposed.*

Keywords*: information and telecommunications system, Ethernet family technologies, OSPF, router delay, neurofuzzy tool, Sugeno, Gaussian function, learning optimizer, epoch, error, intelligent computer network.*

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) [2]. 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 artificial intelligence methods.

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 [5, 7]; neural fuzzy network [6]; ant method [3]; GWO method [4]. For example, in [5] the authors determined the optimal route in the computer network of the ITS of railway transport using 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 based on the created neuro-fuzzy tool for determining the optimal route. In accordance with the goal, the following tasks are set: 1) to create a neuro-fuzzy tool for determining the optimal route in the computer network of railway transport; 2) to determine the optimal parameters of the created neuro-fuzzy tool; 3)to assess the accuracy of determining the optimal route for the considered fragment of the ITS of railway transport using the created neuro-fuzzy tool.

1. Постановка задачі. Figure 1 shows the general structure of the computer network for the considered fragment of the railway transport ITS [5]. 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=30), and W is the edges of the graph (a set of channels connecting routers N=35). The delay on the router, μs, is taken as the weight of the edges.

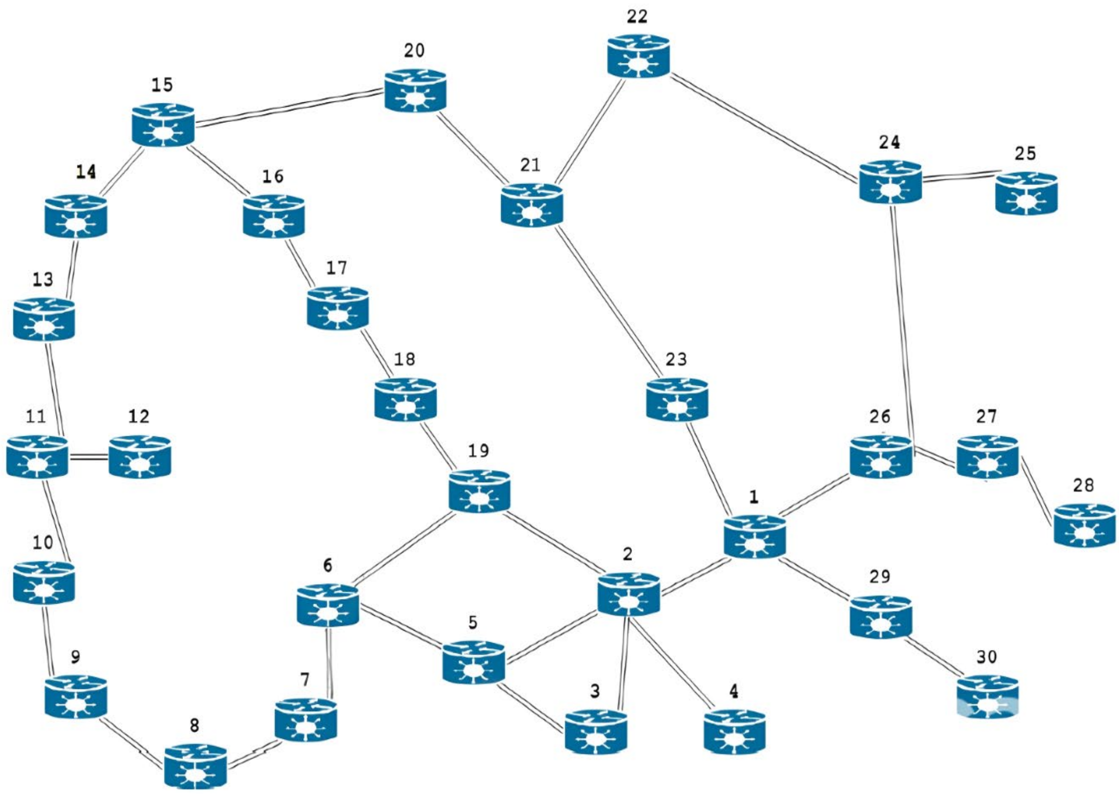

Figure 1 – General structure of the ITS computer network [5]

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 Adaptive Network Fuzzy Inference System (ANFIS) of the configuration «12-24-144-144-1» was taken, where 12 – the number of input neurons (delays on routers); 24 – the number of hidden neurons (due to therms); 144 – the number of hidden neurons, which corresponds to the number of rules; 1 – the number of resulting neurons (total delay on routers along the route), and is shown in Figure 2.

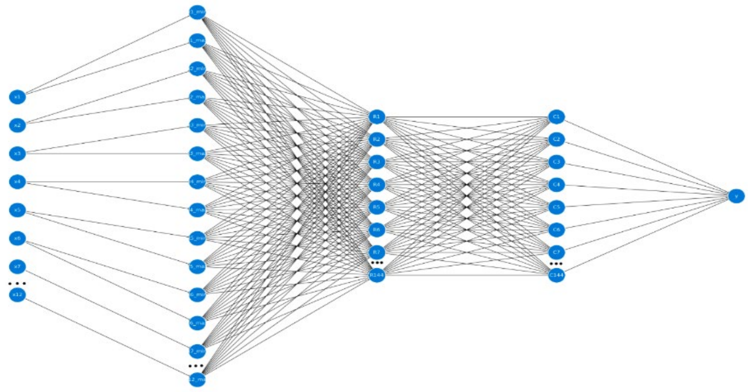

Figure 2 – Structure of the neuro-fuzzy network «12-24-144-144-1»

3. Sample preparation. Suppose that it is necessary to determine the optimal route between two routers: «12» and «28», in the corresponding possible routes it is possible to use 10, 11 or 12 hops. The delay time on the router is from 1 to 500 μs. The resulting variable is the data transfer time along the route (delays on the transmission lines are not taken into account, since they are significantly less than the waiting time in the queue on the routers). The training sample consists of 144 examples.

4. Creation of a neurofuzzy tool. Using the Fuzzy Logic Toolbox package of the MatLAB environment, a neurofuzzy network (ANFIS; Figure 3) was created, the structure of which coincides with the proposed configuration (see Fig. 2).

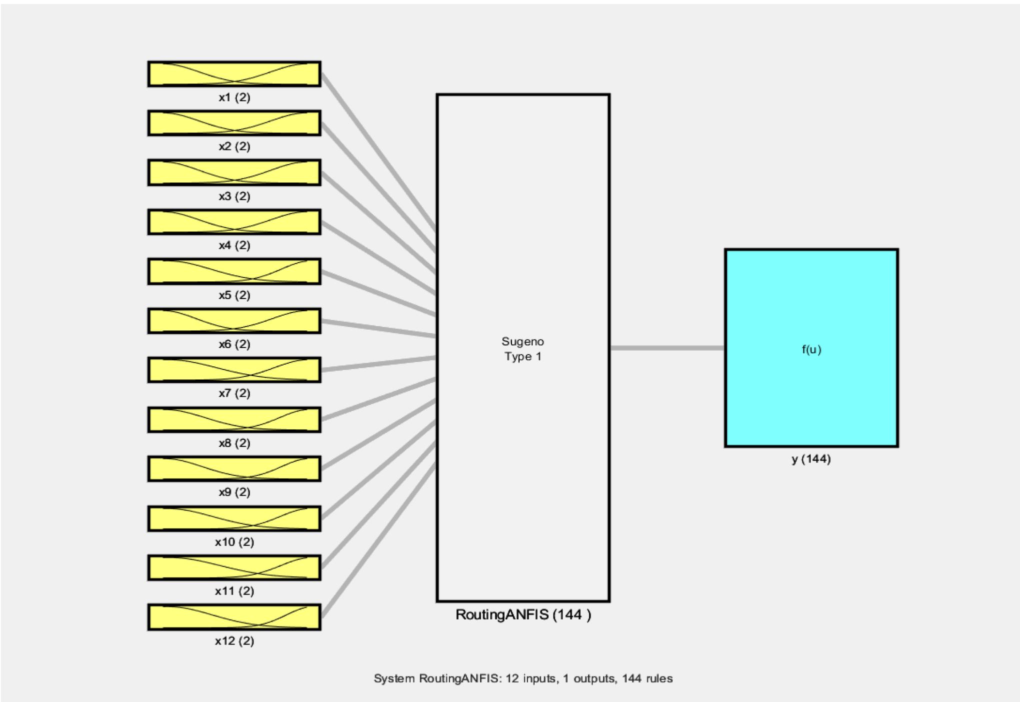

Figure 3 – Structure of a neural fuzzy network created in MatLAB

The Gaussian function is taken as the membership function. The fuzzy rule system is given as follows:

IF x1=MIN I x2=MIN I x3=MIN I x4=MIN I x5=MIN I x6=MIN I x7=MIN I x8=MIN I x9=MIN I x10=MIN I x11=MIN I x12=MIN THEN y=MIN;

…

IF x1=MAX I x2=MAX I x3=MAX I x4=MAX I x5=MAX I x6=MAX I x7=MAX I x8=MAX I x9=MAX I x10=MAX I x11=MAX I x12=MAX THEN y=MAX.

5. Determination of optimal parameters of the created neural fuzzy tool. On the created neural fuzzy network of configuration «12-24-144-144-1», studies of the root mean square error (RMSE) and the number of epochs using different learning optimization methods (Backpropagation, Hybrid) on samples of different lengths (25%, 50%, 75% and 100% of the sample) were conducted, which allowed us to determine the optimal parameters of the neural fuzzy network: learning optimization method – Hybrid; sample length – 50%.

6. Assessment of the accuracy of determining the optimal route using ANFIS. 10 experiments were conducted, according to the results of which the coincidence of the determined route on the created ANFIS with the optimal route was 8 (один із них на рисунку 4). As an example of the discrepancy between the result obtained by the neurofuzzy method and the optimal route is shown in Figure 5.

Conclusions

To determine the optimal route in the computer network of the considered fragment of the ITS railway transport, a fuzzy network of the configuration «12-24-144-144-1» was taken, the resulting neuron of which is the total delay on the routers along the route. Using the Fuzzy Logic Toolbox package of the MatLAB environment, a fuzzy network with a Gaussian membership function was created using the Sugeno algorithm, and its optimal parameters were determined. The accuracy of determining the optimal route in the computer network of the considered fragment of the ITS railway transport based on the use of the created fuzzy tool was 80%.

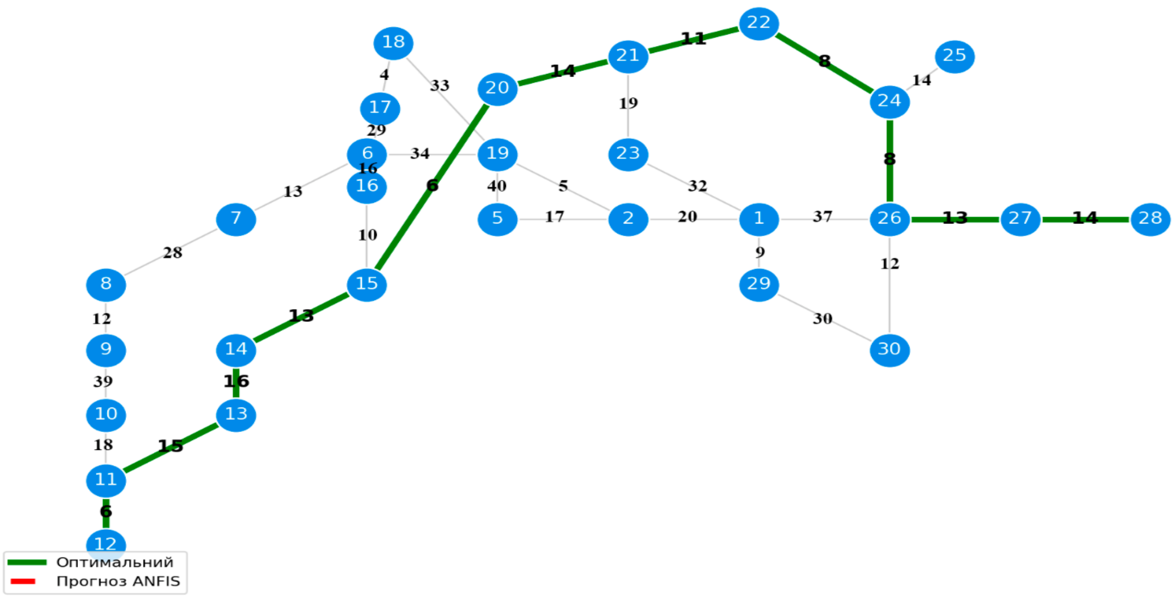

Figure 4 – Route matching

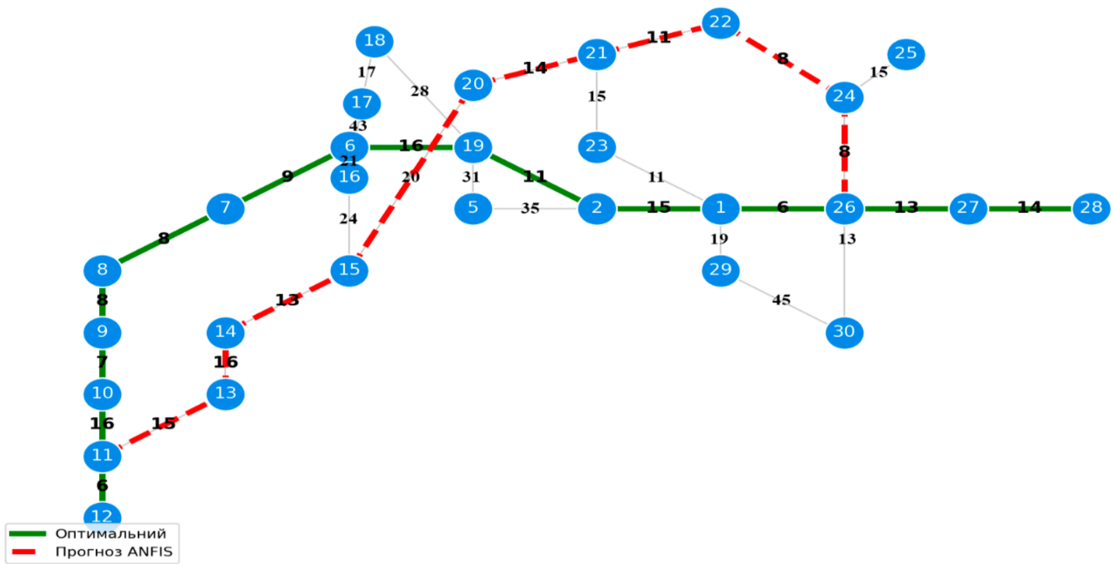

Figure 5 – Optimal and determined path using ANFIS

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Анотація. *На сучасному етапі в інформаційно-телекомунікаційній системі залізничного транспорту застосовуються локальні мережі наступних технологій: Ethernet; Fast Ethernet; Gigabit Ethernet, а також протокол маршрутизації OSPF, при використанні якого в реальному часі з'являється проблема завдяки постійним змінам обсягів передаваємих даних, і для вирішення якої можливий розгляд використання нейронечіткого засобу, що підтверджує актуальність теми. У якості математичного апарату для розв'язання задачі визначення оптимального маршруту взято нейронечітку мережу конфігурації «12-24-144-144-1», де 12 – кількість вхідних нейронів (затримки на маршрутизаторах); 24 – кількість прихованих нейронів з урахуванням термів; 144 – кількість прихованих нейронів відповідно до кількості правил; 1 – кількість результуючих нейронів (загальна затримка на маршрутизаторах за маршрутом). За допомогою пакета Fuzzy Logic Toolbox середовища MatLAB створено за алгоритмом Сугено ANFIS (з Гаусовською функцією належністю для прихованих нейронів), на якій проведено дослідження середньоквадратичної похибки та кількості епох навчання за різними методами оптимізації навчання (Backpropagation, Hybrid) на вибірках різної довжини. Визначено, що точність створеного нейронечіткого засобу складає 80 % для розглянутого фрагменту інформаційно-телекомунікаційної системи залізничного транспорту; запропоновано загальну схему інтелектуальної комп'ютерної мережі на основі ANFIS.*

Ключові слова: *інформаційно-телекомунікаційна система, технології родини Ethernet, OSPF, затримка на маршрутизаторах, нейронечіткий засіб, Сугено, Гаусовська функція, оптимізатор навчання, епоха, похибка, інтелектуальна комп'ютерна мережа.*