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CITY TRANSPORT SYSTEM ECOLOGICAL STATE FORECASTING WITH THE USE OF NEURAL NETWORKS

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Abstract

Purpose: *The purpose of this work is to develop an effective model for city transport system ecological state assessment using neural networks general concept.* ***Methods:*** *The proposed model is based on two neural networks work, taking into account the traffic density effect and the transit capacity level on urban areas.* ***Results:*** *Based on the synthesis of the fuzzy sets theory and neural networks basic principles, the city transport system ecological state assessing model is developed. The graphical representation of the model is given. A forecast reliability high degree is provided even at low learning rates and high dynamics of changing statistical data in the city transit traffic conditions.* ***Conclusions:*** *The use of fuzzy neural networks makes it possible to state a complete correspondence between fuzzy inference procedure mathematical representation and the urban transport system structure. The proposed model allows to formulate well-defined environmental guidelines when making decisions in the transit traffic field, taking into account the interests of enterprises, transport and the urban population, with the subsequent distribution of traffic flows in time and geographical space of the city industrial areas.*

Keywords: city transport system; ecological state; neural network; transit capacity; traffic density.

1. Introduction

Managerial decision-making to reduce the pollution level of cities with different industry profiles and also with different transit freight flows density and dynamics, is one of the primary tasks against the background of a constant increase in the vehicles number in urban areas.

2. Analysis of the latest researches and publications

A sufficient number of scientific works and practical researches are devoted to the environmental protection problem and the transport negative impact reduction on urban areas of industrial regions and nodes [1-3]. At the same time, the issue of transit traffic flows, which affect managing on the environmentally safe development and operation of transport systems, is still unsolved. The presence of a conflict of objectives is due to the fact that, on the one hand, there is a need to improve the urban population life quality by reducing the transport negative influence. On the other hand, the transportation volume growth indicates an effective level of development of industry, transport and business, and leads to an increase in payments to municipal and state budget.

Using of fuzzy neural network theory to obtain high-quality information in an industrial node transport system opens comprehensive facilities [4]. Herewith, the synthesis of fuzzy sets with neural networks makes it possible to ensure the forecast precision and preclude subjectivism in the rules formulation for the system ecological state forecasting. The positive effect resulting from such synthesis is the learning capability, i.e. capability to self consistent adjustment the forecast results on the basis of the statistical data [5-7].

3. Main material

The proposed model is based on two neural networks work, taking into account the traffic density effect and the transit capacity level on urban areas.

The industrial quarters transport flows are represented in the form of "multidimensional structural groupings", which stand for the flows formation with different characteristics number: the transportation destination and direction, the vehicles size and capacity, intensity, regularity and other time characteristics.

Transit capacity, in turn, is determined taking into account the connectivity and straightness of urban industrial areas network, as well as the routes availability [8, 9.10].

The graphical representation of the model shows the actions sequence for calculating the transport system ecological state under research (see Fig. 1).

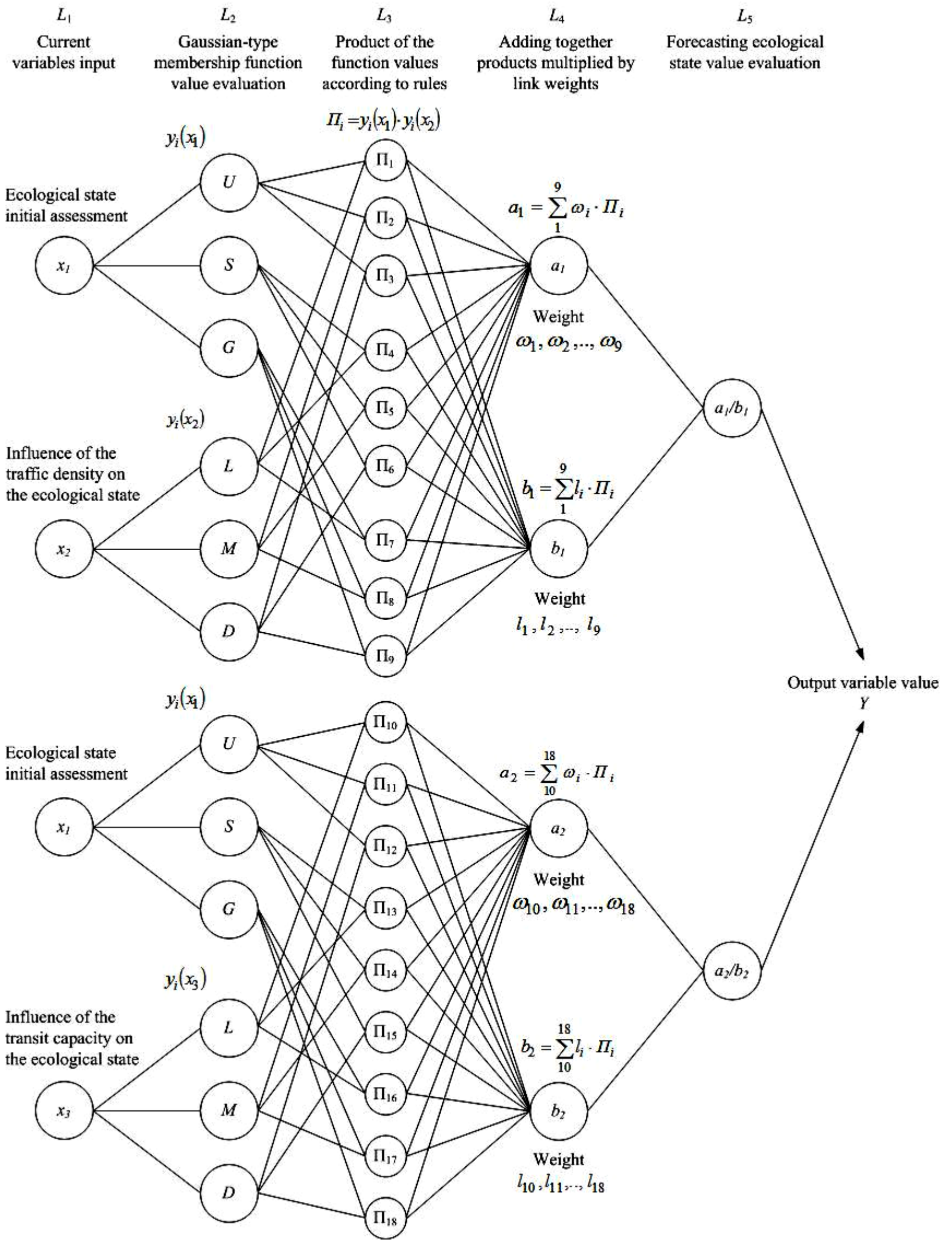

Fig. 1. Graphical representation of the ecological state valuation model

On the first layer (L_1) user inputs data characterizing the initial ecological state level, the traffic density and transit capacity influence:

$$y_i = x_i, \quad (1)$$

where y_i – first layer neurons which are assigned an input variable value; x_i – input variables, which values are set by the user; i – input variable number (i =1...3).

On the second layer (L_2) each first layer variable is represented by three fuzzy set adjective Gaussian-type:

$$y_{ir} = \mu_r(x_i), \quad (2)$$

where $\mu_r(x_i)$ – fuzzy set adjective of input variables set x_i (see Table 1); r – fuzzy set number (i =1...3).

There are fuzzy set adjectives for different type of set names (see Table 1).

On the third layer (L_3), product of the second layer neurons is made, which is a search of possible combinations variants:

$$y_i = \prod_{\substack{i=1...3 \\ r=1...3}} \mu_r(x_i), \quad (3)$$

where j – products number of the third layer neurons (in each of the two nets j =1...9)

On the fourth layer (L_4), the third layer products results summation, multiplied by the connection weight, is performed. As a result, there are only two neurons in this layer:

$$y_a = \sum_{j=1}^{9} \omega_j \prod_{\substack{i=1...3 \\ r=1...3}} \mu_r(x_i)$$
$$y_b = \sum_{j=1}^{9} \prod_{\substack{i=1...3 \\ r=1...3}} \mu_r(x_i), \quad (4)$$

where ω_j – connection initial weight.

Table 1

Formulas for a fuzzy set adjective (second layer neurons)

Name of the set	Fuzzy set adjective
Ecological state initial assessment	
Unsatisfying (U)	$y(x) = \exp\left[-\left(\frac{x-0}{0,2}\right)^2\right]$
Satisfying (S)	$y(x) = \exp\left[-\left(\frac{x-0,6}{0,15}\right)^2\right]$
Good (G)	$y(x) = \exp\left[-\left(\frac{x-1}{0,2}\right)^2\right]$
Influence of the transit capacity	
Name of the set	Fuzzy set adjective
Low (L)	$y(x) = \exp\left[-\left(\frac{x-0}{0,2}\right)^2\right]$
Middle (M)	$y(x) = \exp\left[-\left(\frac{x-0,4}{0,15}\right)^2\right]$
Destructive (D)	$y(x) = \exp\left[-\left(\frac{x-1}{0,2}\right)^2\right]$
Influence of the traffic density	
Name of the set	Fuzzy set adjective
Low (L)	$y(x) = \exp\left[-\left(\frac{x-0}{0,2}\right)^2\right]$
Middle (M)	$y(x) = \exp\left[-\left(\frac{x-0,3}{0,15}\right)^2\right]$
Destructive (D)	$y(x) = \exp\left[-\left(\frac{x-1}{0,2}\right)^2\right]$

On the fifth layer (L_5), the forecast ecological state output value is resulted by dividing the neuron value a by the neuron value b:

$$Y = \frac{y_a}{y_b} \quad (5)$$

The weight numbers adjustment eliminates subjectivity in the fuzzy rules set formulation.

Neural net training algorithm involves the sequence of actions:

1. A training sample is determined on basis of the roads actual survey materials over the previous years. It represents a statistical set of the input variables true values and the output variable corresponding values, i.e. the ecological state forecast level (see Table 2).

Table 2

Training sample with two axons for ecological state assessment

Number of the sample m	True first variable axon value x_1^m	True second variable axon value x_2^m	True output variable synapse value Y_{tr}^m	Calculated output variable synapse value Y_c^m	True error value in forecasting $\varepsilon_{tr}^m = Y_c^m - Y_{tr}^m$
1	x_1^1	x_2^1	Y_{tr}^1	Y_c^1	ε_{tr}^1
2	x_1^2	x_2^2	Y_{tr}^2	Y_c^2	ε_{tr}^2
…	…	…	…	…	…
M	x_1^M	x_2^M	Y_{tr}^M	Y_c^M	ε_{tr}^M

2. The output variable value Y_c^m is calculated for each from training sample *m*-cases, which are also adduced in the array next to the actual data.

3. The average allowable error value for the training cycle is set (ε_{all}), as well as magnitude of velocity value is (η).

4. The weights new links values between the third and fourth layer are calculated by the following formulas:

$$\omega_j^m(t+1) = \omega_j^m(t) + \Delta\omega_j^m, \quad (6)$$

$$\Delta\omega_j^m = -\eta \times y_j \times \varepsilon_{tr}^m, \quad (7)$$

where t – training cycle number.

One training cycle includes all examples search from training sample.

5. Determines the average actual error for the training cycle:

$$\varepsilon_{tr}^m = \frac{\sum_{m=1}^{M} \varepsilon_{tr}^m}{M}. \quad (8)$$

If the true error value throughout the training cycle exceeds the average allowable error value, then return to step 4 is done.

6. Otherwise, learning stops and network is accepted as trained.

4. Results

Simulated result based on the model that uses two neural networks parallel operation has shown error sharp decrease in forecasting the industrial quarters ecological state (see Fig.2).

A forecast reliability high degree is provided even at low learning rates and high dynamics of changing statistical data in the city transit traffic conditions.

5. Conclusions

The use of fuzzy neural networks makes it possible to state a complete correspondence between fuzzy inference procedure mathematical representation and the urban transport system structure.

The proposed model allows to formulate well-defined environmental guidelines when making decisions in the transit traffic field, taking into account the interests of enterprises, transport and the urban population, with the subsequent distribution of traffic flows in time and geographical space of the city industrial areas.

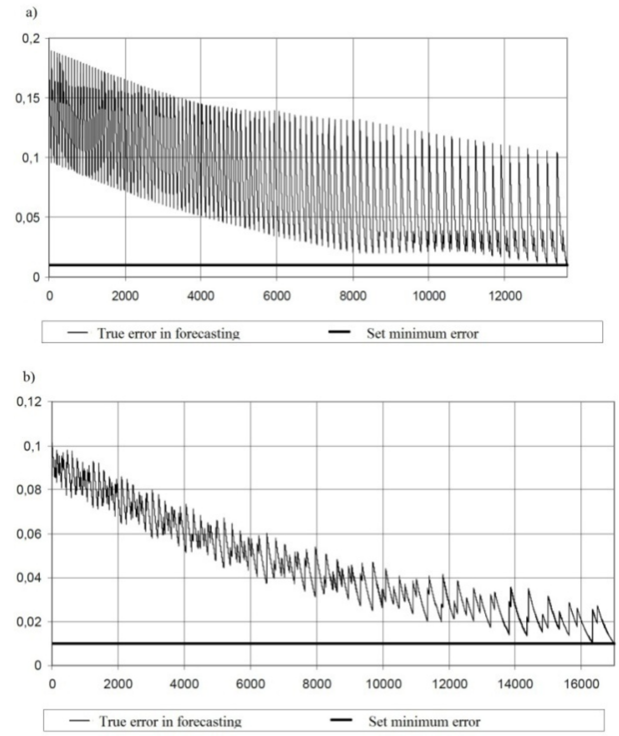

Fig.2. Ecological state forecast error line graphs (a – prior to training start, b – subsequent to the training results)

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Прогнозування екологічного стану міської транспортної системи з використанням нейронних мереж

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Мета: Метою цієї роботи є розробка ефективної моделі оцінювання екологічного стану міської транспортної системи з використанням загальних принципів нейронних мереж. **Методи дослідження:** Запропонована модель основана на роботі двох нейронних мереж з урахуванням впливу щільності транспортного потоку та рівня транзитного потенціалу на урбанізовані райони. **Результати:** На основі синтезу загальних принципів теорії нечітких множин та нейронних мереж розроблено модель оцінки рівня екологічного стану міської транспортної системи. Дано графічне представлення моделі. Високий ступінь достовірності прогнозу забезпечується навіть при низьких швидкостях навчання і високій динаміці змін статистичних даних в умовах транзиту транспортних потоків міста. **Висновки:** Використання нечітких нейронних мереж забезпечує можливість встановлювати повну відповідність між математичним представленням процедури нечіткого висновку і структурою міської транспортної системи. Запропонована модель дозволяє сформулювати чіткі екологічні орієнтири при прийнятті рішень в області транзитних перевезень з урахуванням інтересів підприємств, транспорту і населення міста, з подальшим перерозподілом транспортних потоків в тимчасовому і географічному просторі промислових районів міста.

Ключові слова: екологічний стан; міська транспортна система; нейронні мережа; транзитний потенціал; щільність транспортного потоку.

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Прогнозирование экологического состояния городской транспортной системы с использованием нейронных сетей

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Цель: Целью данной работы является разработка эффективной модели оценки экологического состояния городской транспортной системы с использованием общих принципов нейронных сетей. **Методы исследования:** Предлагаемая модель основана на работе двух нейронных сетей с учетом воздействия плотности транспортного потока и уровня транзитного потенциала на урбанизированные районы. **Результаты:** На основе синтеза общих принципов теории нечетких множеств и нейронных сетей разработана модель оценки уровня экологического состояния городской транспортной системы. Дано графическое представление модели. Высокая степень достоверности прогноза обеспечивается даже при низких скоростях обучения и высокой динамике изменения статистических данных в условиях транзита транспортных потоков города. **Выводы:** Использование нечетких нейронных сетей обеспечивает возможность устанавливать полное соответствие между математическим представлением процедуры нечеткого вывода и структурой городской транспортной системы. Предложенная модель позволяет сформулировать четкие экологические ориентиры при принятии решений в области транзитных перевозок с учетом интересов предприятий, транспорта и населения города, с последующим перераспределением транспортных потоков во временном и географическом пространстве промышленных районов города.

Ключевые слова: городская транспортная система; нейронная сеть; плотность транспортного потока; транзитный потенциал; экологическое состояние.

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