Introduction of modern information and communication technologies in transport flow management

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Abstract. The article proposes an economic mechanism for regulating the route network, the calculation of which allows you to choose a transport route, as well as calculate the number of flights based on the condition of achieving a break-even transport process for carriers of various forms of ownership. The Work deals with the solution of problems related to the choice of a route, which belong to the class of complex combinatorial optimization problems. They don't have simple analytical solutions. As the number of nodes increases, the computational complexity increases exponentially. The Work proposes an alternative method for solving routing problems based on the use of neural network models, which allow obtaining good suboptimal solutions with a significant reduction in time costs. As in the Hopfield network, a matrix of neurons is used here, but neurons interact not on the "each with each" principle, but in rows and columns.

1. Introduction
To fully meet the needs of road traffic management, it is necessary to improve the standards and quality of transport services and bring them into line with international standards, ensure the safety, popularity, reliability and stability of transport services, improve infrastructure, apply flexible tariffs and new promising directions. It is also necessary to carry out a number of targeted measures for the formation and digitalization of the transport system in order to fully meet the demand of the population for urban passenger transport services [1-3].

A number of targeted measures are being taken to widely introduce modern information and communication technologies in the management of passenger transportation, and much attention will be paid to improving the safety and quality of urban passenger transport, improving traffic efficiency, and further optimizing the movement of bus routes together with other types of passenger transport, including existing and newly built lines of the Tashkent Metro [4-5].

For the successful construction, planning and operation of the future urban transport system, the public transport sector must be aware of the latest technological developments. One of the most promising developments in recent years is the introduction of this artificial intelligence [6-9]. Artificial intelligence has changed our way of working in all areas and even started to affect our daily lives. The opportunities that these technologies bring to the public transport sector vary: from customer service to better quality service. Artificial intelligence has already begun to change the future of transportation services [10-12].
2. Mathematical model of the problem

Problems related to the choice of a route, planning the operation of communication facilities, etc., belong to the class of complex combinatorial-optimization problems, as a rule, which do not have simple analytical solutions. In addition, the complexity of the required computations increases exponentially as the number of nodes in the network increases. Therefore, at present, various heuristic algorithms and procedures are widely used, obtained through creative search, intuition and the experience of the researcher. An alternative to existing methods for solving routing problems is the use of neural network models, which allow obtaining good suboptimal solutions with a significant reduction in time costs. Thus, models based on the Hopfield neural network are widely used to solve combinatorial optimization problems, which were first used to solve the traveling salesman problem. These models were the beginning of the development of neural methods for solving complex optimization problems. Most of the subsequent studies were based on them in one way or another [13-14].

The channel allocation problem is a mathematical problem related to graph coloring [8]. It is known from theory that the time required to find a solution increases exponentially with an increase in the dimension of the problem (that is, an increase in the number of base stations).

The neural network model for solving a combinatorial optimization problem was first introduced by Hopfield and Tank [9]. The solution to the problem is to minimize the generated energy function.

The mathematical model of the problem is as follows [15]:

\[
R = \sum_{i=1}^{n} \sum_{j=1}^{n} r_{ij} z_{ij} \rightarrow \min .
\]

\[
\begin{align*}
\sum_{j=1}^{n} z_{ij} &= 1, \quad i = 1, n; \\
\sum_{i=1}^{n} z_{ij} &= 1, \quad j = 1, n; \\
z_{ij} &\in \{0; 1\}, \quad i = 1, n \quad j = 1, n.
\end{align*}
\]

Hopfield and Tank showed an approach to its approximate solution based on Hopfield networks. Let's take a quick look at this approach. To describe possible routes, the authors have proposed a special type of matrix. In it, cities form rows, and columns display the sequence of cities in the route [16]. The position \((x, i)\) of the matrix contains 1 in the case when the city \(x\) takes the \(i\)-th place in the route.

In the case of \(n\) cities, there are different routes \(\frac{n!}{2n}\), among which it is necessary to find the shortest. To obtain a solution, the problem is displayed by the Hopfield network.

In it, each neuron is denoted by two indices \(x\) and \(i\), and \(x\) reflects the city, and the \(i\)-th position in the route, i.e. \(z_{xt}\) the output of the neuron where the city \(x\) is located at the \(i\)-th position of the route.

The following conditions are imposed on the energy function \(E\) of the Hopfield network:
- it should be minimal only for feasible solutions that contain one unit in each row and in each column of the route description matrix;
- it should take smaller values for solutions with shorter routes.

An energy function satisfying these conditions can be as follows:

\[
E = A \sum_{x} \sum_{i} \sum_{j \neq i} z_{xi} z_{xj} + \frac{b}{2} \sum_{x} \sum_{i} \sum_{j \neq i} z_{yi} z_{xi} + \frac{C}{2} \left( \sum_{x} \sum_{i} z_{xi} - n \right)^2 \\
+ \frac{D}{2} \sum_{x} \sum_{i} \sum_{j} r_{xy} z_{xi} \left( z_{yi+1} + z_{yi-1} \right)
\]

Choosing it, the followings were taken into account:
- the first term is zero only in cases where each row of the arrow description matrix contains only one unit;
- the second term is zero only when each column of the matrix contains only one unit;
- the third term is zero only in cases where there are n units in the model description matrix, which means: each city is visited only once;
- the fourth term reflects the length of the route. We note that for each city X, located on the i-th position, the distance is RXY to its follower Y on the position I + 1 and its predecessor Y in position I - 1.

The use of Hopfield networks is limited to a high computational complexity (n^4 where n is the dimensionality of the problem) and the need to carefully select the parameters of the energy function and the activation function of the neuron. The situation can be significantly simplified if you apply the following approach.

To solve problems (1) - (2), a recurrent neural network was proposed [8], which is described by the differential equation [16]:

$$\frac{\partial u_{ij}(t)}{\partial t} = -\eta \left( \sum_{k=1}^{n} z_{ik}(t) + \sum_{l=1}^{n} z_{lj}(t) - 2 \right) + \lambda r_{ij} \exp \left( -\frac{t}{\tau} \right),$$

where

$$z_{ij} = f(u_{ij}(t)), \quad f(u) = \frac{1}{1 + \exp(-\beta u)}.$$

As in the Hopfield network, it uses a matrix of neurons in size, but neurons interact not on the principle of "each with each", but in rows and columns [17].

The difference version of this equation has the form:

$$u_{ij}^{t+1} = u_{ij}^{t} - \Delta t \cdot \left[ \eta \left( \sum_{k=1}^{n} z_{ik}(t) + \sum_{l=1}^{n} z_{lj}(t) - 2 \right) - \lambda r_{ij} \exp \left( -\frac{t}{\tau} \right) \right],$$

where $\Delta t$ - time step. The parameters are selected experimentally and significantly affect the speed of achieving a solution to the problem and the quality of this solution.

3. Computational experiment.

A computational experiment was carried out to find the optimal route and the results (figure 1).

![Figure 1. Solving the routing problem](image-url)

The proposed approaches not only solve the problem more accurately, but also allow taking into account, in addition to the technical characteristics of the route, its cost, reliability and other parameters.

References
[1] Trofimenko M R 2013 Transport planning: the formation of efficient transport systems in large cities: Monograph (Moscow: Logos)
[2] Vaksman S A 2012 Information technologies in the management of urban public passenger transport (tasks, experience, problems) (Yekaterinburg: AMB Publishing House).
[3] Menukhova T A 2014 Methodology for determining the required number of vehicles in a limited time interval for cargo delivery. Transportation Research Procedia 209 189-192
[4] Menukhova T A 2017 Using of Regionalization Techniques to Select Optimal Routes Based on Criteria of Road Features. Transportation Research Procedia 20C 436-442
[5] Nordin V 2016 Urban traffic problems of Kaliningrad and their solution. Auxiliary systems in mechanical engineering Review of Problems and Solutions 3 (15) 97-105
[6] Brusyanin D A 2015 Approach to the formation of an optimal route network of passenger public transport at the regional level. Transport of the Urals 1 31-34
[7] Syzy S V, Vikharev S V, Brusyanin D A, Nizovtseva I G 2013 Bulletin of Petersburg University of Railways 3 (36) 73-79
[8] Rachek S V 2007 Innovative approaches to improving the technology of transport services. Bulletin of Siberian State University of Railways 19 84-89
[9] Ponomareva M S 2014 Economic mechanisms of regulation of the transport complex of the region Kazan science 4 63-68.
[10] Koryagin M E 2012 Theoretical aspects of optimization of urban transport traffic management Bulletin of Kazbass State Technical University 1 (89) 125 - 126
[11] Muhamediyeva D K 2020 Study parabolic type diffusion equations with double nonlinearity. IOP Conf. Series: Journal of Physics: Conference Series 1441 012151
[12] Ziyadullayev D Sh, Mukhamedieva D T, Ziyodullaeva G E, Ibadullaeva Z J 2018 Develop the student model Journal of Advanced Research in Dynamical and Control Systems – JARDCS 10(14)
[13] Ziyadullayev D Sh, Mukhamedieva D T, Ziyodullaeva G E 2018 Development of mathematical model of lesson schedule formation system Journal of Advanced Research in Dynamical and Control Systems – JARDCS 10(14) 1850 – 1854
[14] Abdullaev Z, Yusupov M, Mirzaev S, Noraliev N, Kusharov Z 2020 Dynamic Dampers of Vibrations of Inherited-Deformable Systems with Finite Number of Degrees of Freedom. International Conference on Materials Physics, Building Structures and Technologies in Construction, Industrial and Production Engineering (MPCPE-2020) Russia, April 27-28
[15] Ravshanov Z N, Abdullayev Z S, Khafizov O Ya Atmospheric dispersion modeling of dust emissions from the dried bottom of the Aral Sea. International Conference on Materials Physics, Building Structures and Technologies in Construction, Industrial and Production Engineering (MPCPE-2020). Russia, April 27-28, 2020
[16] Mirzaev S S, Tukhtanazarov D, and Karimova Kh Kh 2020 Software for Determining Residual Oil Reserves in Oil Deposit Development. Construction Mechanics, Hydraulics and Water Resources Engineering (CONMECHYDRO – 2020). Tashkent Institute of Irrigation and Agricultural Mechanization Engineers. 23-25 April.
[17] Aynakulov Sh, Karimova X, Mamajonov M., Alibekov S, Shakirov B 2020 Constructive device for sediment flushing from water acceptance structure. International Conference on Materials Physics, Building Structures and Technologies in Construction, Industrial and Production Engineering (MPCPE-2020). Vladimir, Russia, April 27-28.