TRAINING AI TO FIND THE SHORTEST PATHS ON GRAPH MODELS

A. L. Abramov[1], N. B. Vasileva[1], D. A. Sukhanov[2]

[1] *Far Eastern Federal University, Vladivostok, Russia*
[2] *Scientific and educational center of the Federal Tax Service of Russia and Bauman Moscow State Technical University, Russia*
E-mail: abramov.al@dvfu.ru, vasileva.nb@dvfu.ru, dsuhanov@emtc.ru

This study focuses on the use of the domestic applied artificial intelligence system "RAZUM AI" to solve problems of finding the shortest paths on graphs, which are models of real systems and are used for planning tasks. The aim of the work is to develop a module that implements algorithms for solving problems on graphs, with subsequent integration into the domestic applied AI system "RAZUM AI".

The results of the study can be used for continuous planning problems in logistics for the selection of routes, placement of networks of production, engineering and social infrastructure, presented in the form of a “network of networks”.

The article presents the development of a module for solving extreme problems on graphs, based on the hardware and software platform of the domestic AI "RAZUM AI". The module includes applications for loading graph data, automated processing and conversion of data, and outputting results to a dashboard. The trained AI platform is designed for interactive search for solutions to problems without the need for direct coding by the user.

Complex networks, as an independent subject of research, appeared in the middle of the last century [1]. The study of such networks is associated with the practical experience of their existence. Competencies in the functioning and development of complex networks are in demand in various fields, such as economics, management, law, cultural studies and engineering.

The management system of a complex network must be flexible in order to adapt changes. The interaction of the network and the management system occurs through management bodies and institutions that determine the rules of conduct within the network.

A complex network is a multi-channel repeater that ensures communication "from everyone to everyone". The efficiency of this repeater affects the quality of management.

The key tasks of management are planning the allocation of resources, investments, programs and infrastructure.

In recent years, methods of applied artificial intelligence have been used to solve such problems to find the shortest paths, centres, clusters, etc.

Import-substituting technologies, including applied artificial intelligence (AI) systems, are actively developing in Russia. Since 2022, the BAUM AI system has been developed and implemented at the Scientific and Educational Centre for Artificial Intelligence Technologies at the Bauman Moscow State Technical University. In 2023, the system came under the control of AiB LLC and became part of the RAZUM AI software [2].

The RAZUM AI platform allows training artificial intelligence models to solve problems in various fields, such as industry, education, and healthcare.

One of the RAZUM AI modules is a module for solving extreme problems on graphs. As an example, we can consider the primary graph model of a city, which is a graph of a transport network.

To each edge (v_x,v_y) of the original undirected graph $G(V,A)$, (V is the set of vertices, n is the number of vertices, A is the set of edges, m is the number of edges) we assign a number $C(v_x,v_y)$. If the graph does not contain an arc (v_x,v_y), then $C(v_x,v_y) = 0$. The number $C(v_x,v_y)$ is called the weight/length of the edge, and the graph G is called weighted. We define the length of a chain as the sum of the weights of individual edges that make up this chain.

Under such conditions, there are several formulations of finding the shortest paths in the graph: between a given pair of vertices; between a given vertex and all remaining vertices of the graph (tree of shortest paths); shortest paths between each pair of vertices; K shortest paths between all pairs of vertices.

The problem of finding the shortest paths between a given pair of vertices. For any two vertices v_s and v_t of a graph G, there may be several paths connecting the vertex v_s with the vertex v_t.

Let us consider an algorithm of applied artificial intelligence that determines such a path leading from the vertex v_s to the vertex v_t and having the minimum possible length. This path is called the shortest path (in a directed graph, the shortest path) between the given vertices: v_s and v_t.

The mathematical task of the finding the shortest paths between a given pair of vertices problem is as follows. Let G be a connected undirected weighted graph. The problem of finding the shortest path is to find a subgraph $G_{st}(V_{st},A_{st})$, that includes the shortest path (paths) from a given vertex v_s to the vertex v_t, the sum of edge weights is minimal (V_{st}, is the set of vertices in the shortest path, A_{st} is the set of edges in the shortest path, C_l^{st} are the weights of the edges included in the shortest path):

$$\varphi: G = (V, A) \rightarrow \left\{ G_{st} = (V_{st}, A_{st}) | V_s, V_t \subset V, \min_{l} \sum_{l \in V} c_l^{st} \right\}$$

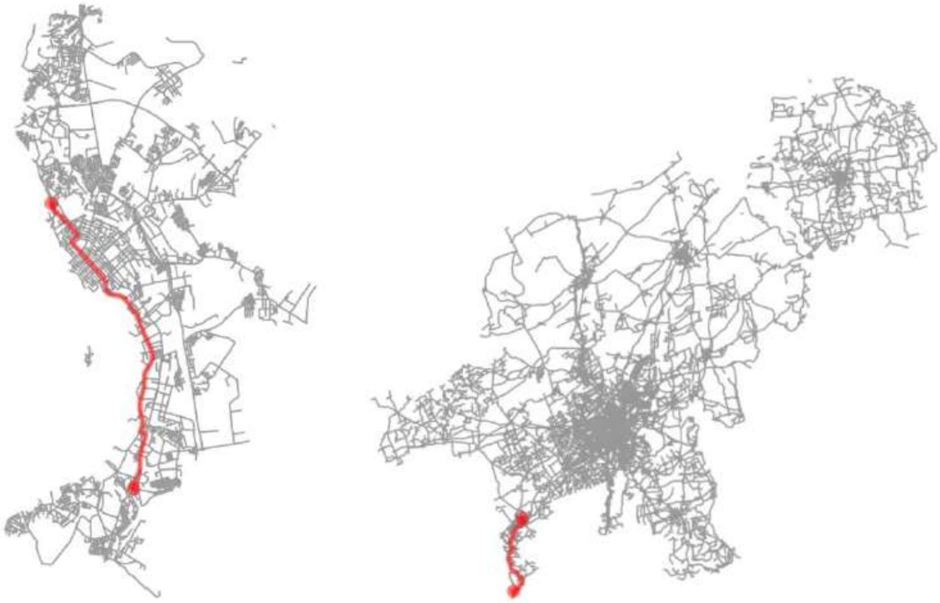
To solve this problem in the case where the edge weights are non-negative and there are no cycles of negative weight in the graph, an efficient artificial intelligence algorithm for finding the shortest path between a given pair of vertices or a tree of shortest paths was used - SPAPV with polynomial complexity $O(n^2)$ [3].

To implement the SPAPV algorithms, in 2022-2024, work was carried out to train the applied AI "BAUM AI", and from 2023 onwards - on the AI platform "RAZUM AI" algorithms for finding the shortest paths using the example of graph models of cities [3-5]. Thus, on the platform, within the framework of the module for solving extreme problems on graphs, users now have the opportunity to build pipelines that interact with graph models and allow solving planning problems using different algorithms on the same data sets.

Pipelines make it easier for users without programming skills to solve continuous planning problems. They allow solving problems of placement, forecasting and programming of socio-economic development in different areas, for example, for regions and cities.

To test the module for solving extreme problems on graphs in the RAZUM AI system city models built on the basis of OpenStreetMap (OSM) data are used. OSM is an open database containing information about cities of the world.

The graph model of the city within the module is built as follows. At the lower level is the primary graph, in which the vertices and edges are elements located on a plane/surface. Such graphs can display both geometric and topological properties of the real settlement system, places of application of forces, street network, etc.



a b

The result of the module's work to find the shortest path between two given vertices (SPAPV algorithm) on the primary graph model; a – Khabarovsk, Russia; b – Changchun, China

The SPAPV algorithm used allows solving infrastructure placement planning problems, considering the interests of the municipality and owners.

A graph model of a city using shortest path search algorithms not only optimizes planning tasks, but also ensures "everyone-to-everyone" communication, facilitating effective management.

The RAZUM AI module, trained in shortest path search algorithms, can be used in various areas, including planning, training, supply and demand forecasting, chain optimization, disease spread modelling, resource management, automation of robotic systems, and much more [6, p. 37-39; 7, p. 45-46].

The module allows users without programming skills to solve planning problems for complex networks, such as regions and cities.

Work on expanding the algorithm base in the module continues. This direction is promising for increasing efficiency and innovation in the economy and social sphere of the Far East.

The work was carried out with the financial support of the Ministry of Science and Higher Education of the Russian Federation and the achievement of the results of the federal project "Advanced Engineering Schools" (No. 075-15-2022-1143 dated 07.07.2022) within the framework of the agreement concluded between the FEFU and the BMSTU.

REFERENCES

1. *Abramov A. L., Velichko A. S., Kozlovkaya A. K., Drekko E. V., Anoshkina M. A., Molochkova M. A.* Graph models of complex networks // The 32nd International Conference of the Jangjeon Mathematical Society. [Electronic resource]. URL: DOI dx.doi.org/10.24866/7444- 4647-5. 2019. Vol. 76 (6). P. 5-8. (access date: 25.09.2024).

2. RAZUM AI. [Electronic resource]. URL: https://ai-aib.ru/ (access date: 05/09/2024).

3. *Velichko A. S., Abramov A. L., Anferova E. N., Matvienko N. N., Vasilyeva N. B., Gorik Yu. R., Pugach P. A., Podgorny A. S., Zgurya D. S., Nedoshivina A. A., Syzhipova S. O., Ogneva M. G.* Research report. Development of system analysis algorithms and applied artificial intelligence for forecasting and planning in the field of national economy, bioeconomy, protection and management of natural biological resources. Stage 2. Code 9N: Advanced engineering schools. State program of the Russian Federation “Scientific and technological development of the Russian Federation”. – Vladivostok: Far Eastern Federal University, 2023. P. 363.

4. *Abramov A. L., Vasilyeva N. B., Velichko A. S., Pugach P. A.* Certificate of state registration of the computer program RU 2023682957. Interactive search for shortest paths in graph models of cities for the hardware platform of artificial intelligence BAUM AI. Publ. 01.11.2023.

5. *Abramov A. L., Vasilyeva N. B., Gorik Yu. R., Pugach P. A.* Certificate of registration of the database RU 2023623074. Database of graph models of Russian cities with a population of over 100 thousand people. Publ. 09.11.2023.

6. *Ogar T. P., Stepanchenko I. V., Krushel E. G., Panfilov A. E., Kharitonov I. M.* Analysis of data on the structure of the public transport route network using the example of the city // Vestnik ASTU. Series: Management, computer technology and information science. 2022. No. 1. p. 33-41.

7. *Kalyashina A. V., Evdokimova T. S., Erkhov V. Yu.* Designing the trajectory of a robot in a limited space // Vestnik VSTU. 2022. No. 4. p. 44-49.