AP19680292 “Development of an expert system of decision-making on the issues of fastening and maintenance of mine workings” - p.m. Tomilov A.N.

Relevance

The main distinction of the developed software product lies in the combined use of heuristic and algorithmic methods, which makes it possible to provide the most optimal results in response to user queries.

The knowledge base of the expert system contains rules (or other forms of knowledge representation), which serve as the foundation for decision-making. The inference mechanism includes general knowledge of the decision-making process structure. This mechanism comprises two components: the interpreter and the dispatcher. The first determines how rules are applied to derive new knowledge, while the second establishes the sequence of applying these rules. The knowledge base editor is intended for modifying the rules of the expert system and for inputting new knowledge.

Project Goal

The project aims to create a domestic expert system designed to provide solutions related to the reinforcement and maintenance of mine workings, using both heuristic and algorithmic methods to deliver optimal results. The knowledge base and the core software of the expert system are intended to be deployed using cloud technologies.

Expected and Achieved Results

The main outcome of the project implementation is the creation of a domestic expert system designed to deliver solutions regarding reinforcement and maintenance of mine workings by combining heuristic and algorithmic methods. For hosting the knowledge base and core software, cloud technologies are planned to be used.

As a result of using the expert system, optimal parameters for different types of support structures for any cross-sections of mine workings will be proposed, including parameters and methods for maintaining mine workings, identifying zones of damage in the surrounding rock mass while accounting for changes in mining and geological conditions, considering the time factor to determine expected displacements and loads.

The modular architecture of the expert system will allow its further expansion to solve a wide range of geomechanical tasks.

At the current stage, the expert system has been tested together with specialists from external scientific organizations to verify the adequacy of the solutions provided.

In 2025, the following results were achieved: the software was adapted to solve applied engineering problems. Tools for data input, editing, and visualization were implemented, and the stability of the system was confirmed during practical problem-solving. Testing was conducted with the participation of experts from external scientific and design organizations, who confirmed the correctness of the expert conclusions generated by the system and its applicability in a production environment.

Based on the 2025 trials, the expert system was recognized as ready for pilot-industrial testing. This implies its use at mining enterprises, comparison with traditional design methods, and preliminary assessment of the potential for integration into practice. A formal act confirming the successful completion of the testing stage and the agreement of its results with external experts has been obtained.

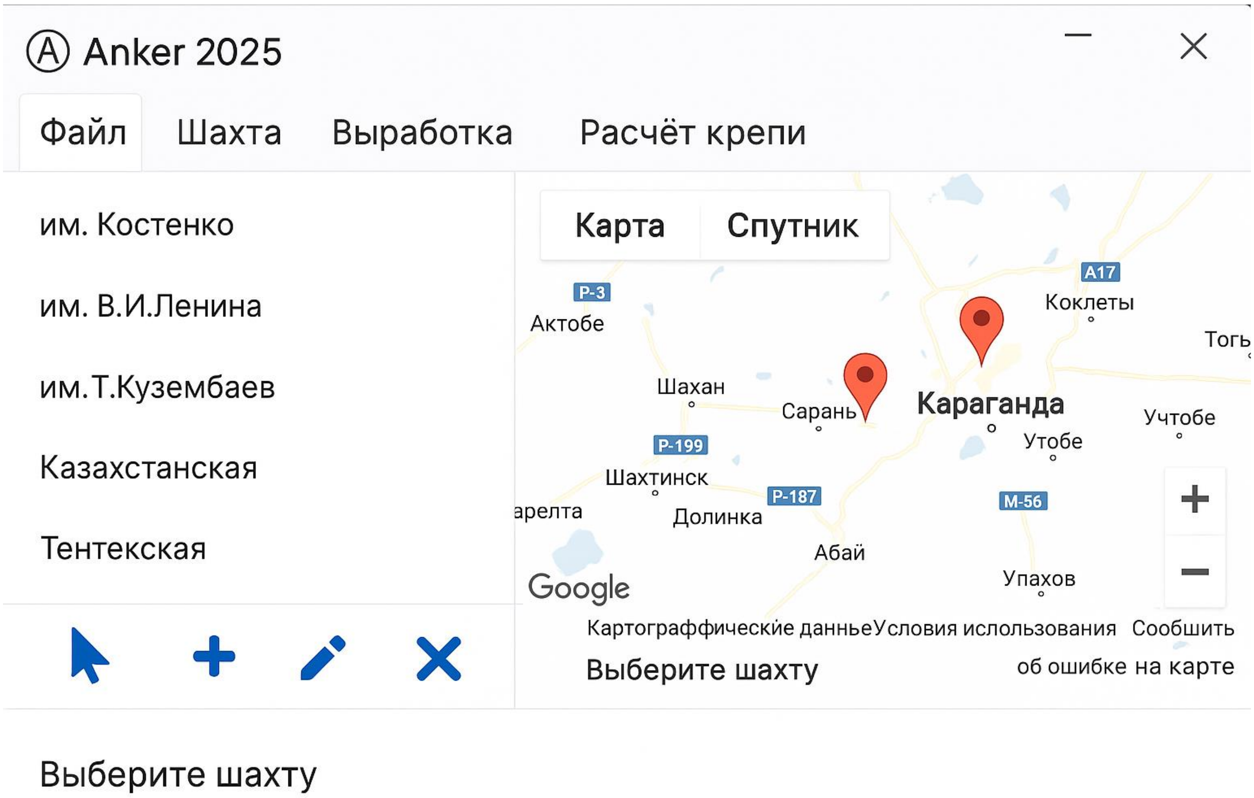

Figure 1 – Mine Identification

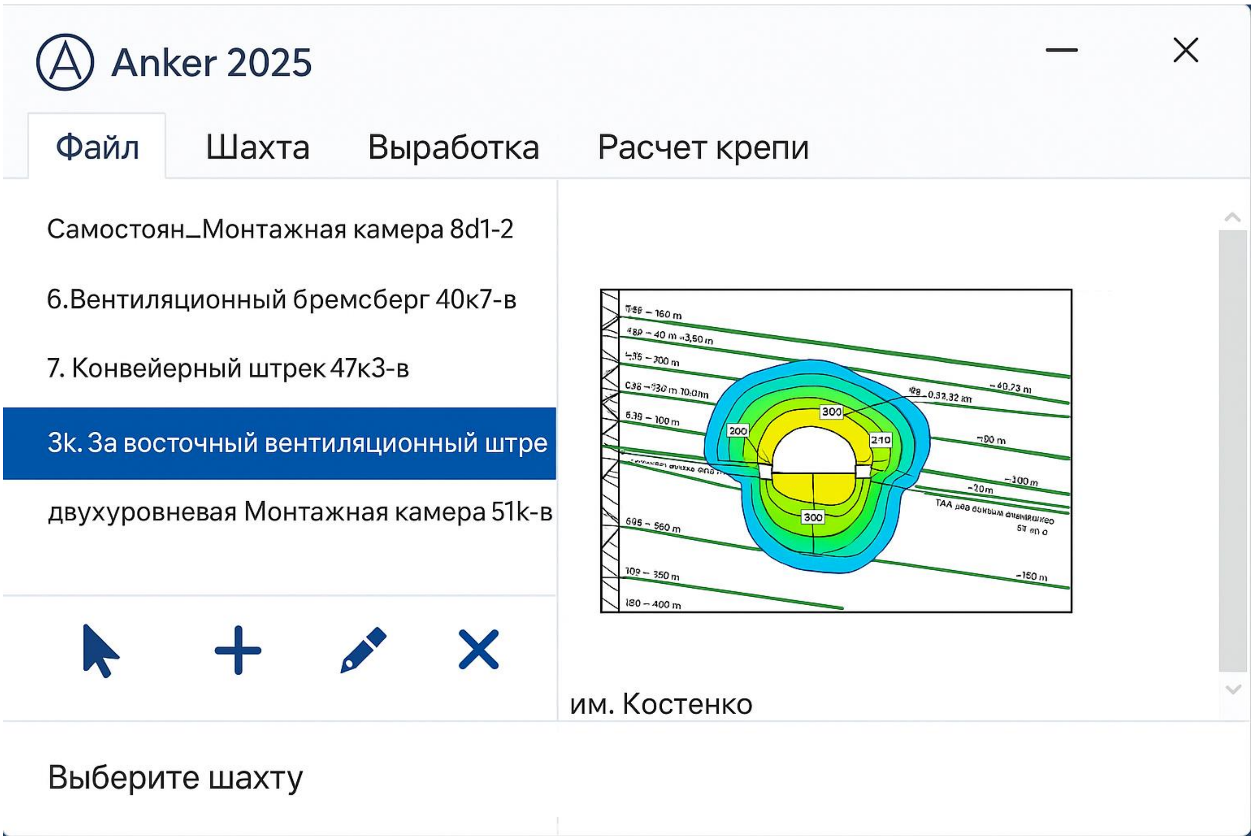

Figure 2 – Mine Workings Identification

In Figure 3, it was demonstrated that most workings were located at depths of 400–800 m, with the roof characterized by strength ranging from 25 to 50 MPa, and displacements ranging from 30 to 60 mm, reflecting the actual conditions of the Karaganda coal basin.

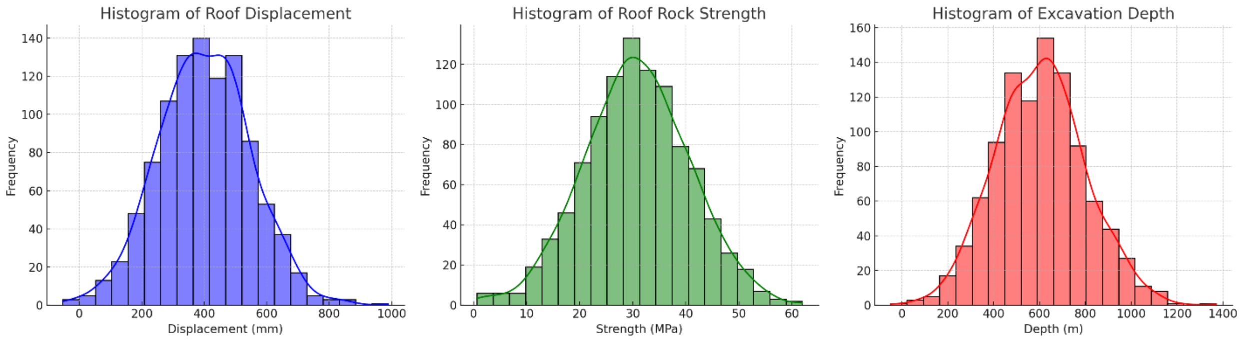

Figure 3 – Histograms of depth, roof strength, and roof displacement distribution

For additional analysis of parameter variability, boxplots were constructed to depict median values, interquartile ranges, and outliers.

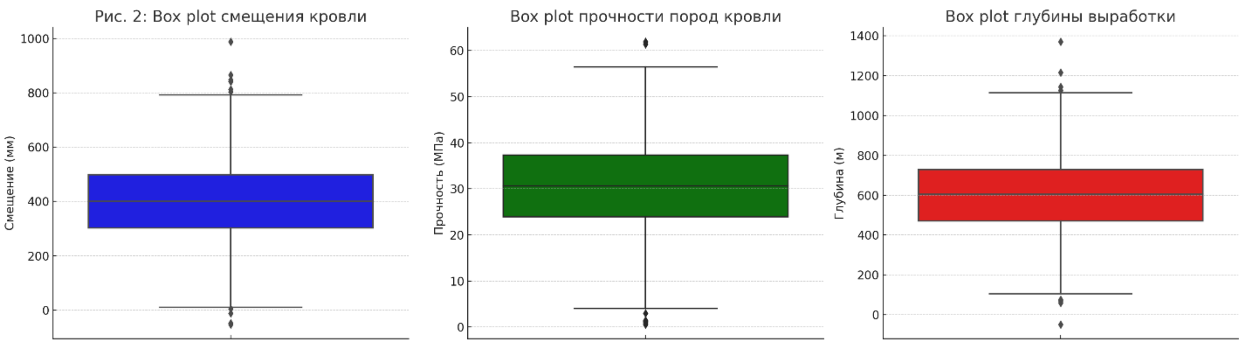

Figure 4 – Boxplots of key rock mass parameter distributions

Besides the charts, this subsection included Table 1, which contained examples of typical parameters of actual workings used for model training. These data were obtained from field observations and integrated into the system's knowledge base.

Table 1. Example data from the knowledge base on the stability of mine workings

Mine	**Depth (m)**	**Width (m)**	**Height (m)**	**Cross-Section Shape**	**Influence of Other Workings**	**Roof Strength Rc (MPa)**	**Moisture Coefficient**	**Roof Displacement (mm)**
Kazakhstan	448	5.4	3.5	Arched	Isolated	45	0.47	40.3
Kazakhstan	466	5.5	3.8	Rectangular	Adjacent	42	0.50	42.8
Karagandinskaya	600	6.0	4.0	Arched	Intersection	35	0.55	50.2
Central	900	5.2	3.6	Arched	Intersection	28	0.60	65.5

Analysis of these data revealed patterns essential for predictive modeling: increasing depth and moisture content correlated with higher roof displacements, whereas higher rock strength values, on the contrary, were associated with reduced deformations.

Thus, visualization and systematization of the initial parameters made it possible to confirm the reliability of the original dataset and lay the groundwork for high-quality training of stability prediction algorithms.

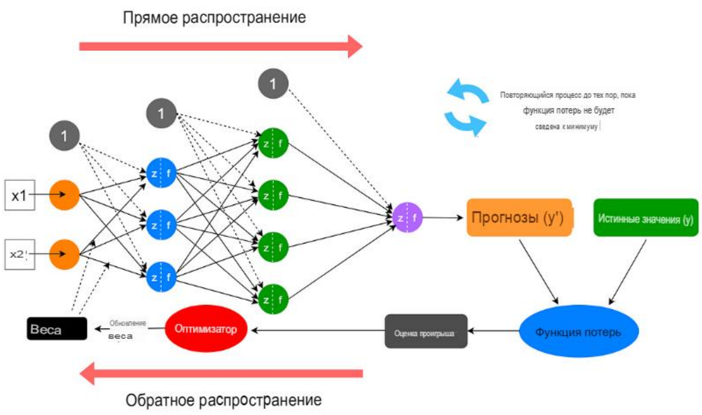

Figure 5– Neural Network Training Process

The figure shows the schematic of an artificial neural network algorithm, including the stages of forward and backward error propagation.

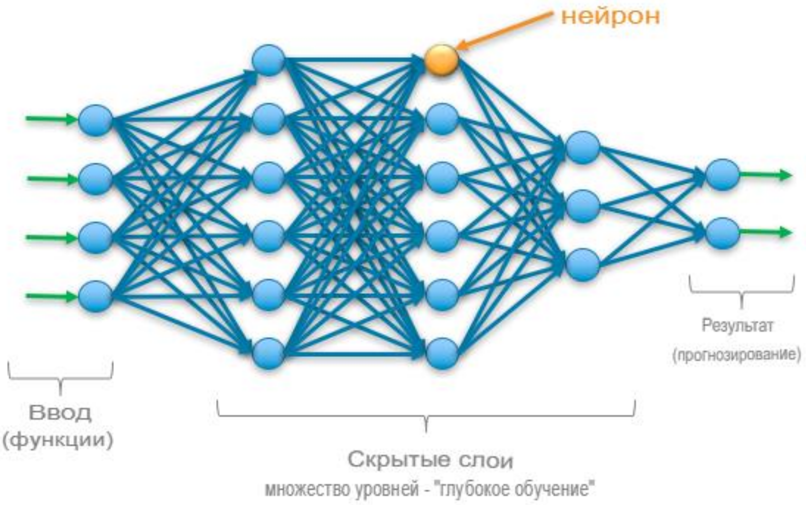

Figure 6 – Deep Learning Architecture with a Multilayer Neural Network

The figure depicts the architecture of an artificial neural network (ANN), illustrating its key components and operational principles.

Additionally, the figure presents a schematic of the **ETL (Extract, Transform, Load)** process, one of the main data processing methods for further analysis or storage.

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List of Publications and Expected Publications

Articles included in Scopus databases with a percentile of at least 65

1. Vladimir Demin, Alexey Kalinin, Murat Baimuldin, Aleksandr Tomilov, Natalya Mutovina, Assemgul Smagulova, Denis Shokarev, Samat Aliev, Assem Akpanbayeva, and Tatiana Demina. “Developing a Technology for Driving Mine Workings with Combined Support and Friction Anchors in Ore Mines.” https://doi.org/10.3390/app142210344, www.mdpi.com/journal/applsci
2. Vadimir Demin, Alexey Kalinin, Nadezhda Tomilova, Aleksandr Tomilov, Assemgul Smagulova, Natalya Mutovina, Denis Shokarev, Anton Popov, Rustam Shakirtov, Tatiana Demina. “Digital Modeling of the Stress–Strain State of Rock Masses to Enhance the Stability of Underground Mine Workings.” Appl. Sci. 2024, 14, x. https://doi.org/10.3390/xxxxx, www.mdpi.com/journal/applsci
3. Natalya Mutovina, Margulan Nurtay, Alexey Kalinin, Aleksandr Tomilov, Nadezhda Tomilova. “Application of Artificial Intelligence and Machine Learning in Expert Systems for the Mining Industry: Modern Methods and Technologies.” International Journal of Electrical and Computer Engineering (IJECE). https://doi.org/10.11591/ijece.v15i3.pp3291-3308
4. Aleksandr Tomilov, Alexey Kalinin*, Nadezhda Tomilova, Margulan Nurtay, Natalya Mutovina, Kirill Shtefan. “Expert System for Assessing the Stability of Underground Excavations based on Machine Learning Methods and Numerical Modeling.”

Articles recommended by the Ministry of Education and Science of the Republic of Kazakhstan

1. Mutovina N., Smagulova A., Demin V., Baimuldin M., Tomilov A. “Development of an Expert System for Fixing and Maintaining Mine Workings in the Mining Industry.”
University Proceedings, No. 3, 2023, pp. 400–406.
2. Mutovina N.V., Smagulova A.S., Demin V.F., Tomilov A.N. “Optimization of Anchor Support Parameters for Mine Workings Considering Operating Conditions: Analysis of Mines in the Karaganda Coal Basin.” University Proceedings, No. __, 2025, pp. __.

3. Tomilov A.N., Utyashev A.R., Tomilova N.I., Mutovina N.V. "Improving the Stability of Distributed Systems Using the Fault-Tolerance Mechanism of Elixir/OTP."
University Proceedings, No. __, 2025, pp. __.

Monograph in a foreign publishing house

1. Tomilov A.N., Demin V.F., Tomilova N.I., Mutovina N.V. "Justification of Parameters and Automation of Calculation of Anchor Support of Mining Workings."
Urbana: Arrow Science & Technology, LLC, 2025.
236 pages.
DOI:10.29013/JPACASMW.TomilovA.N.DeminV.F.TomilovaN.I.MutovinaN.V.236.2025

Certificate of Intellectual Property of the Republic of Kazakhstan

1. Smagulova Asemgul Serikovna, Kalinin Alexey Anatolyevich, Mutovina Natalya Viktorovna, Tomilov Aleksandr Nikolaevich.
"Software for Calculating the Effect Obtained as a Result of Extracting an Enlarged Pillar."
Date of creation: 09.06.2025.

The following are planned to be published:

- 4 (four) articles and/or reviews in peer-reviewed scientific journals indexed in the Science Citation Index Expanded and included in the first and/or second quartile by impact factor in the Web of Science database and/or with a CiteScore percentile in the Scopus database of at least 65.
- 3 (three) articles or reviews in peer-reviewed foreign or domestic publications recommended by the Committee for Quality Assurance in the Field of Science and Higher Education.
- 1 monograph in a foreign publishing house.
- 1 Certificate of the Republic of Kazakhstan on the registration of intellectual property rights.

Information for Potential Users

The expert system for reinforcement and maintenance of mine workings can be useful to all those engaged in mining and underground construction, providing analytical data on rock properties, stability assessments of mine workings, and methods for their maintenance.

Companies specializing in mine, tunnel, underground structure, and mining facility construction may use the system to develop and apply optimal reinforcement and maintenance methods.

The system provides users not only with information and recommendations but also with tools for making informed and well-founded decisions, which helps enhance safety, efficiency, and reliability of mining and construction projects.

Field of Application

Field of application: Surveying and geotechnical services of mining enterprises, enabling prompt decision-making on reinforcement and maintenance of mine workings based on empirical and algorithmic methods.

The knowledge base includes regulatory calculation methods for reinforcement parameters, ensuring compliance with all safety standards for mining operations adopted in the Republic of Kazakhstan.

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