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Artificial intelligence in geophysics: opportunities and risks

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The article briefly reviews some artificial intelligence methods successfully used to process and interpret logging data and for seismology and geothermy. The possibilities of artificial neural networks, the Support Vector Machines, the Random Forest method, and genetic algorithms are highlighted. The basic information about the advantages and limitations of artificial intelligence tools is given.

AI is not self-sufficient for geological and geophysical research. It is important to adapt its algorithms to work with large volumes of geophysical data. If the algorithm has too high computational complexity, calculations can be simplified by manually processing the input data or using conventional software. Sometimes, several algorithms are used to solve a single problem. In such cases, each network is trained several times. When comparing the results with approximately equal control errors, a computationally simpler neural network is chosen.

For the purpose of better orientation in the computing world, information is provided on the computational adaptation of artificial intelligence to geophysical data.

Attention is drawn to the possibility of financial risks associated with the use of an insufficiently powerful network when modeling a particular dependence.

Key words: artificial intelligence, algorithm, seismology, geothermy, interpretation of logging data.

Introduction. The development of artificial intelligence (AI) methods is inextricably linked with the emergence of information theory. Although references to the first prototypes of modern machine intelligence date back to the ancient period. In the relict works of physicists and mathematicians of the last century, one can find many valuable recommendations and tips necessary for orientation in the modern information world, where AI technologies occupy a strong position.

The practical application of information theory in Earth sciences has paved a barely noticeable path to geoecology. And this path took almost three decades. The rational use of information theory in any field of science is possible if one prerequisite is met — a clear understanding of the mathematical essence of the fundamental category «information» and its computational apparatus.

Having access to huge amounts of data, allows scientists to find dependencies and anomalies in experimental materials faster, and then put the results into practice in a shorter time period. It is not necessary for a researcher to have an exhaustive knowledge of the fundamentals of computational mathematics. However, he must have a sense of mathematical order, namely, to easily identify single facts and pay close attention to the hidden dependencies of «distant» facts from each other. The «soul» of a fact, as pointed out by the French mathematician A. Poincare, will forever remain outside the

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«activity field» of the machine intelligence.

This paper is devoted to an analytical review of some artificial intelligence methods that have successfully proven themselves in the process of processing and interpreting experimental geophysical material.

A brief description of some AI methods and an analysis of their effectiveness. Direct applicability of AI methods to Earth sciences is insufficient. The biggest difficulty is the choice and combination of tools. It is necessary to carefully analyze which methods and why should be used to study a particular phenomenon.

An interesting combination of two machine learning algorithms (GAN and Random Forest) was developed by the authors [Li et al., 2018] to solve the noise problem.

GAN is a neural network, the subject of which is the basic distribution of data. The input data for the generator is a random distribution, including noise. Next, the generator examines the display function, with which the data is transformed into the desired result. At this stage of the work, it is not yet known whether the generated data is real. Here, a discriminator is needed, the key role of which is to evaluate the output data of the generator. The discriminator is a binary classifier that takes the output data from the generator and evaluates the probability of the data being fake or real.

The device proposed by [Li et al., 2018] is trained to recognize the characteristics of P-waves data. This eliminates the need to manually define and select waveform characteristics. Random Forest uses the main characteristics of these functions and classifies the types of signals with high accuracy. Both algorithms were trained on a large volume of seismic data: 300000 P-waves and more than 300000 noise signals recorded in Southern California and Japan.

By combining GAN and Random Forest, Li et al. [2018] achieved excellent results in recognizing earthquakes against the background of other pulsed noise signals, which can significantly reduce the number of false alarms of the EEW (Earthquake Early Warning) system.

The method development for the automatic identification of earthquakes based on large amounts of data is the primary seismological research task. To accurately identify seismic events, Liu et al. [2022] proposed a combined GAN and SVM model. 52537 recordings of strong earthquakes in Japan were used to train GAN and extract the P-wave characteristics. Next, the SVM algorithm is used to detect earthquakes and micro-earthquakes. The results show that the combined model provides an accuracy of 99.74 % for P-waves and 99.93 % for micro-vibrations.

The study [Wang et al., 2019] suggests an innovative and constructive solution for the identification of sedimentation microformations based on the SVM algorithm application. The accuracy of the algorithm reaches 84 %. This technology will help save the cost of core analysis and increase the profitability of oil and gas exploration.

The ecology of our planet sets its priorities in the choice of energy sources. For several decades, scientists have been improving the technologies for the development of «green energy». This type of energy is a renewable energy resource that is inexhaustible for humans and can serve for many years. The main difficulty in using «green energy» is the selection of suitable areas of the earth's surface and their integration into the local infrastructure.

There are many technological problems in the operation of the thermal power plant. The choice of a geothermal plant construction site ultimately determines its future reliable and uninterrupted operation. AI offers a wide range of effective tools to solve this problem processing a sufficiently large experimental array of geothermal data. Next, geoinformation data is analyzed: access to infrastructure, potential risks of equipment malfunctions, assessment of the impact of the station's activities on the environment.

Based on generalized reviews [Kong et al., 2016; Rouet-Leduc et al., 2017; Perol et al., 2018], some important performance characteristics of AI methods in geological and geophysical conditions were identified. The information is given in Table.

Conclusions. In the last few years, re-

Brief characteristics of artificial intelligence algorithms

The algorithm name	Sample size for training	Tasks	Computational complexity
Support Vector Machines	The definitive answer depends on the specific task. You can use data with a lot of noise	Tasks of linear and nonlinear classification, regression, and detection of abnormal data	Linear in the number of support vectors
Random Forest	Moderate. Increasing the amount of data will lead to ignoring some important features	Forecasting lithology based on logging data	Depends on the data set
Genetic algorithms	Sample size for training	Any type of optimization tasks. Electromagnetic sensing	High optimal accuracy increases with calculation time

searchers have been using AI algorithms with ensemble learning. This approach helps to increase the accuracy and objectivity of interpretation results, but it can significantly increase the financial cost of computational calculations.

The practice of implementing algorithms in geological and geophysical conditions has shown the adaptability of machine learning methods. In other words, self-tuning is taking-place when the geological and geophysical environment changes.

One of the main characteristics of AI is computational complexity. There are no universal methods, so the information given in Table is concise on the one hand, and on the other hand, it may suggest the way to the required method or a combination of them.

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Штучний інтелект у геофізиці: можливості та ризики

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Наведено короткий аналітичний огляд деяких методів штучного інтелекту, які успішно застосовуються в процесі обробки та інтерпретації даних каротажу, а також у сейсмології та геотермії. Висвітлено можливості штучних нейронних мереж, методу опорних векторів, методу випадкового лісу, генетичних алгоритмів. Надано основні відомості про переваги та обмеження інструментів штучного інтелекту.

Для геолого-геофізичних досліджень штучного інтелекту не є самодостатнім. Важливо пристосувати його алгоритми до роботи з великими обсягами геофізичних даних. Якщо використовуваний алгоритм має надто високу обчислювальну складність, можна спростити обчислення за допомогою ручної обробки вхідних даних або звичайного програмного забезпечення. Іноді застосовуються кілька алгоритмів для вирішення одного завдання. У таких випадках кожну мережу навчають кілька разів. При порівнянні отриманих результатів із приблизно рівними контрольними помилками вибирають простішу в обчислювальному відношенні нейронну мережу.

З метою кращої орієнтації у світі обчислень наведено інформацію про обчислювальну адаптацію штучного інтелекту до геофізичних даних.

Звернено увагу на можливості фінансових ризиків, пов'язаних із використанням недостатньо потужної мережі при моделюванні тієї чи іншої залежності.

Ключові слова: штучний інтелект, алгоритм, сейсмологія, геотермія, інтерпретація каротажних даних.