Artificial Intelligence Methods Application in Oil Industry

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***Abstract*— The article provides an overview of the methods of artificial intelligence — artificial neural networks and support vector machine, as well as the main areas of their application in the oil and gas sector. In this work three main areas of use of such technologies are investigated: interpretation of geological data, price forecasting and flow regime forecasting. The use of methods based on artificial intelligence increases the efficiency of the work carried out both in exploration and production-makes it possible to achieve better results with less cost. In the new market conditions formed in the energy and mining sectors, it is essential to use all available mechanisms to improve efficiency. It is very convenient to use data mining methods at all stage of oil production.**

Keywords—artificial intelligence; neural networks; raw materials industry; oil and gas sector

I. INTRODUCTION

The decline in oil and other commodity prices over the past two years has posed a serious challenge to mining companies. Low prices encourage them to look for new innovative solutions-ways to improve efficiency as the current operational activities and strategic planning. One of these areas is artificial intelligence [1]. Artificial intelligence is the ability of computer systems to mimic human intelligence in performing various tasks: (1) training (perception of information, its processing and determination of rules of its use), (2) inference (application of these rules for making certain conclusions and decision-making), (3) self-correction (self-correction of errors taking into account accumulated experience), etc. Artificial intelligence competes with human in accuracy, power and speed.It is able to perceive huge amounts of data, quickly structure them, perform analysis and give the output the desired result (depending on the loaded data and the task — pattern recognition, management, forecasting, etc.).

The most popular applications of artificial intelligence are image recognition (texts, images, speech, faces, etc.), "computer vision" (a technology that allows computers to identify, track and classify objects), machine translation, game programs, data processing and analysis and much more. Artificial intelligence plays a significant role in the work of the oil and gas industry-from the interpretation of geological data to the actual production of hydrocarbons. Its involvement leads to lower costs and increase production efficiency [2]. The most common methods based on artificial intelligence are artificial neural networks (ANN) and support vector machine (SVM).

II. NEURAL NETWORKS

Artificial neural network (ANN) - mathematical model of a biological neural network that mimics the work of the human nervous system and brain. The ANN is composed of the Unitedand interacting simple processors-artificial neurons.At its core, ANN is an information processing mechanism - a learning-capable computer system with many independently occurring processes. In the course of training, which can be carried out with a "supervisor" or even without it, the neural network perceives the input data, adjusts them, changing its structure and internal parameters, and then outputs the transformed data [3, 4].

Traditional neural networks of the 1980s and 1990s had a number of restrictions in use, which restrained their widespread use, for example, extremely long training time — as the number of inputs and internal layers of the network increases, the time required for training increases exponentially. An additional characteristic problem of ANN is the unsuccessful of the final result and the inability to understand how this result was obtained (black box effect).

An effective method of training multilayer neural networks appeared later and was called "deep learning" (deep learning). This method is a kind of machine learning and involves multi-level processing of information using nonlinear transformations. Thanks to "deep learning" complex ANN are able to learn from their experience without a "teacher", forming in the process of learning multilevel hierarchical data structure [5, 6].

At the moment, there are several large research centers in the world that are engaged in the development of algorithms based on neural networks — for example, the laboratory of the Massachusetts Institute of technology (MIT) belongs to them. In Russia, the leading organization in this area is the computer center of the Russian Academy of Sciences. A. A. Dorodnitsyna initially the emphasis was on such areas as speech and text recognition, "computer vision" in robotics.

Today artificial intelligence plays an increasingly important role plays in the work of the oil and gas industry - from the

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interpretation of geological information to the actual production of oil and gas. Its application allows you to reduce the associated costs and improve the efficiency of operations.

Let us focus in more detail on those areas of the oil and gas sector and other raw materials industries where artificial intelligence has already been introduced into real practice.

III. Functionally Separable Support Vector Machine (FS-SVM)

The support vector machine method is the most powerfull linear classifier method [7]. The main idea of the basic SVM method is to classify objects by translating the original vectors describing the objects into a space of higher dimension and finding a separating hyperplane with a maximum gap in this space. Two parallel hyperplanes are constructed on both sides of the hyperplane separating the classes. A separating hyperplane is a hyperplane that maximizes the distance to two parallel hyperplanes. The algorithm works under the assumption that the greater the difference or distance between these parallel hyperplanes, the smaller the average error of the classifier [8].

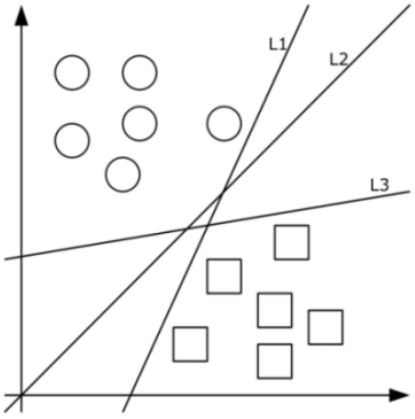

Fig. 1. Several classifying dividing lines (hyperplanes), of which only one corresponds to the optimal separation

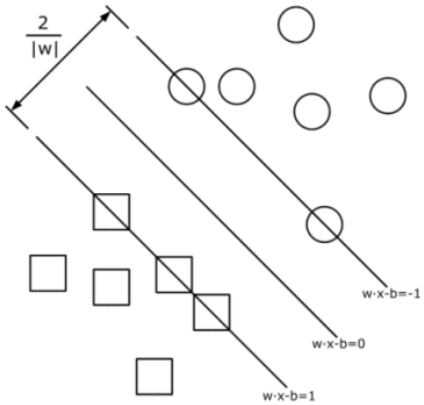

Fig. 1. The optimal dividing hyperplane for the support vector method based on points from two classes. Points closest to parallel hyperplanes are called support vectors

It should be noted that the operation of the support vector algorithm in the general case is associated with cumbersome calculations, which can lead to unreasonably high computational costs (finding the saddle point of the Lagrange function, applying the kernel method, etc.) [9]. Also significant are the drawbacks of the SVM method, consisting in the absence of a general approach to the automatic selection of the kernel and the construction of a rectifying subspace as a whole in the case of linear separability of classes.

In this regard, it is necessary to develop a modification of the support vector method that allows for high accuracy in solving the classification problem (like the standard SVM method in the nonlinear case using the kernel function), and at the same time, with less computational and algorithmic complexity.

To this end, it is proposed to impose some restrictions on the problem under consideration, which will allow us to develop and apply a modified method of support vectors. As a limitation, one should not consider the general problem of classifying classes of arbitrary shape, but the task of classifying under the condition of "functionally separable" classes.

The following definition of functional separability is suggested: classes are functionally separable if there is a functional relationship between each output parameter and the set of input parameters. Moreover, this function is continuous and monotonic on the set of values of the input parameters. That is, cases are excluded in which, for the problem domain, in one of the projections of the output variables onto the set of input variables, it is possible that one class is included in another class.

Let us consider in detail the operation of the modified method of support vectors - Functionally Separable - Support Vector Machine (FS-SVM).

The FS-SVM algorithm is as follows.

First, a search is performed for support elements, that is, class elements that are located on the class boundary. Elements are ordered by one of the coordinates with fixed values of the other coordinate. A pair of elements for which the class value changes are marked as supporting elements. This procedure is repeated for the remaining coordinates of the elements.

Then, a search is made for points for the separating hypersurface. The vectors connecting the supporting elements of each class are calculated, and the minimum distance is determined for each of them. The middle of the vector connecting these support elements of the classes is calculated. The resulting point is defined as the point through which the separating hypersurface should pass. The indicated procedure is repeated for all supporting elements of classes.

A separating hypersurface is constructed as a piecewise linear function in projection onto the coordinate axes under consideration.

IV. Interpretation of Geological Data

Artificial neural networks are successfully applied in the solution geophysical and geotechnical problems. The involvement of ANN allows to reduce the required number of wells and conducted tests to determine the characteristics of soils and reservoir properties, leading to significant savings in money and time [10]. For example, the use of neural networks

in mapping soil layers in Northern Iran showed a high degree of accuracy of prediction of trained models based on ins-about 90% (when compared with data from test wells) [11].

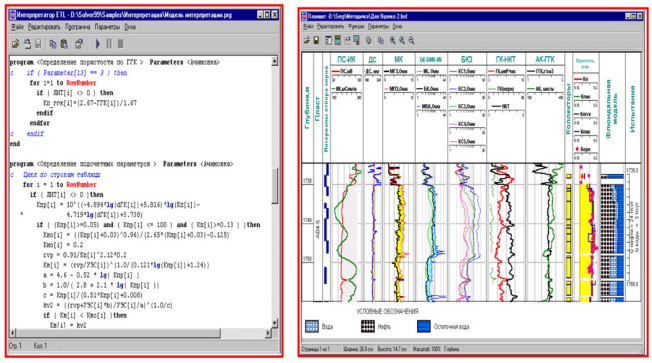

Fig.3. The analysis of geological data

The use of neural networks reduces the cost of research, improves the quality of geological assessment and facilitates the interpretation of the structure of underground layers. The usefulness of ANN it is explained by their ability to process a large amount of data, work with nonlinear relationships, adapt to changing conditions, generalize and learn [12].

Artificial neural networks, along with linear regressions, are used to predict various geophysical parameters (for example, reservoir properties such as porosityand the effective thickness of the formation), for the construction of curves of geophysical studies of wells. ANNs are also used in Geophysics for interpretation of logging data, interpretation of seismic data, definitions of lithological structure and boundaries of geological objects, analysis of water saturation and permeability [13].

The analysis of geological data is extremely important for the assessment of oil and gas potential of the studied areas. Artificial neural networks make it possible to analyze a geological section based on seismic data (the most effective geophysical method for finding hydrocarbons). The use of artificial intelligence in this direction increases the efficiency of exploration, increasing their speed and accuracy and reducing costs [14, 15].

V. Price Forecasting

Another area of application of artificial intelligence was the prediction. Due to the significant decline in the prices of minerals (including oil, coal and many metals), there is a demand for better methods of analysis of commodity markets.

The use of artificial intelligence in forecasting opens up new opportunities for describing and predicting events in both financial and commodity markets. The power of analytical methods based on artificial intelligence is that they accurately simulate the behavior of market participants and reflect the social specifics of economic relations.

Very often commodity companies develop their own forecasting models of prices for sold raw materials. Majoritysuch models are based on traditional econometrics-regression multifactor models. The main advantages of methods based on artificial intelligence compared to traditional econometric models are:

- contextual information processing;
- adaptability of models and their ability to learn;
- error tolerance;
- absence of necessity to pre-process data;
- automatic selection of the optimal model.

With the help of artificial intelligence methods, it becomes possible to iterate over a much larger number of models, when this machine can simultaneously apply different combinations of methods (for example, neural networks together with the method of support vectors). In this case, it is possible to choose not only from a larger absolute number of models, but also from a larger number of different types of models [15].

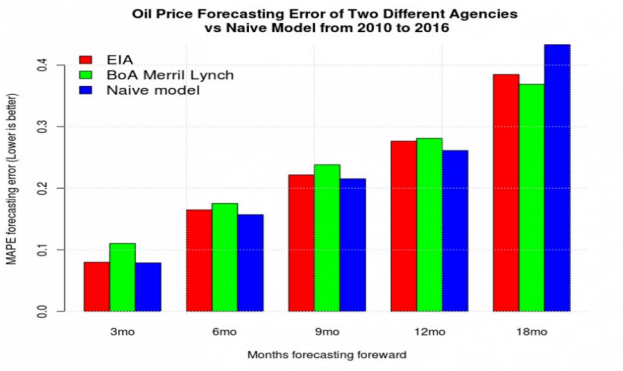

Fig. 4. Results prices forecasting

At the moment, a number of methods based on artificial intelligence have been developed, which are used to develop commodity price forecasts, but neural networks remainthe most popular of them. Due to the fact that neural networkscan work with complex, multi-format and even incompletefor example, they are suitable for dealing with non-linear, non-stationary and volatile series, which include commodity prices.

VI. Practical Application of the FS-SVM Method. The Task of Classifying the Flow Regimes of an Oil-Water-Gas Stream.

The considered restriction of the functional separability of classes is not critical for a large number of tasks. In particular, this condition will be true for problems in which the initial data are obtained as a result of observation of physical phenomena with the established monotonicity of their origin. One of such tasks is the problem of determining the flow regimes of an oil-water-gas stream. Consider this task in more detail.

An oil field consists of a set of well clusters. Each well cluster contains about ten oil producing wells having their own physical characteristics (oil density, average production rates, amount of impurities, and others). Pumps of various types and capacities are installed at oil wells.

During oil production, oil, water contained in the reservoir and associated petroleum gas are simultaneously produced. At the same time, it is necessary to constantly monitor the costs of

each fraction to dynamically change the operating mode of the well pump.

For example, if it is not timely discovered that a large proportion of the volume of produced products is gas, then "pumping" of the pump may occur, which will lead to its idle operation and well shutdown.

Also, with a significant increase in the proportion of water in the produced mixture, it is necessary to reduce the speed of the pump, or even turn it off for a while. In this case, it is necessary to give the oil reservoir time to separate oil from the soil layer, and continue production after some time.

These parameters are continuously monitored at the wellhead using a multiphase flow meter. A monotonic relationship between the controlled flow parameters and its flow regimes is established. There are four main classes of two-phase flow regimes in vertical channels: bubble, shell, emulsion and dispersion-ring modes [16].

In this problem, it is necessary to solve the problem of classifying the controlled parameters of an oil well according to the flow regimes of the oil-water-gas stream. The figure shows a projection of the classification results obtained using the FS-SVM method for a set of archive values of well parameters. The results are consistent with theoretical predictions.

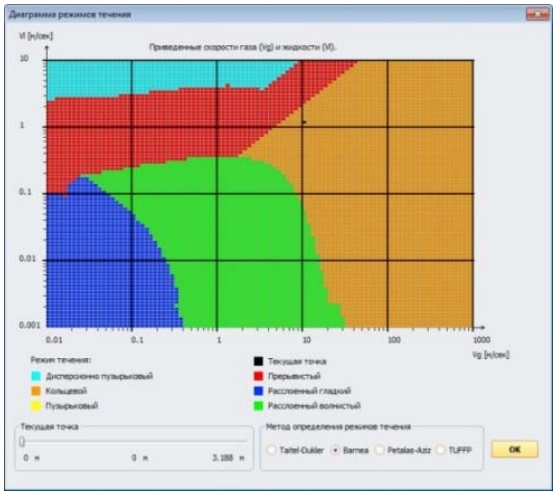

Fig. 5. Design regimes of two-phase flow in vertical channels

Thus, it is shown that the problem under consideration can be successfully solved using the method developed by FS-SVM.

VII. Conclusion

Both of the described methods have advantages and disadvantages. Artificial neural networks are the "black boxes" and they are not completely studied. Thus in some cases ANN can achieve a result with a very high precision, but some cases can fail. The SVM method is intuitively clear, but it has a lot of computing complexity. The FS-SVM method was developed to eliminate disadvantage of SVM, by imposing a restriction on problem domain. It is shown that the considered restriction of the functional separability of classes is not critical for a large number of tasks, for example for some tasks, with have physical nature, such as oil production and oil-water-gas flow regime forecasting.

Also artificial intelligence methods, especially neural networks, are actively used in geological exploration and hydrocarbon production. Interpretation of the geological data enables the analysis of data of geophysical researches of wells (GRS), well logging, seismic characterization of reservoirs, etc. Such methods can improve the efficiency of operations, reducing costs and increasing the result.

Another important area of application of artificial intelligence is the forecasting of raw material prices, on which the profits of mining companies and their development strategy depend. Models based on artificial intelligence can accurately reproduce complex behavior in commodity and stock markets, describe and predict volatile time series. At the same time, they do not require preliminary data processing, manual search and selection of the optimal model. They can work with missed and erroneous observations, they are able to self-study and retrain with the appearance of new relevant data.

Acknowledgment

Thus, artificial intelligence methods have a number of advantages over traditional approaches and can become a suitable tool to improve the efficiency of mining companies in a period of low commodity prices.

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