Use of artificial intelligence methods to solving problems in oil production industry

Yuliya Lind, Jan Awrejcewicz, Aigul Kabirova, Azamat Murzagalin, Anna Khashper

Abstract: The general approach to engineering of systems in oil and gas industry from the aspect of their automation and use of information technologies including design and experiment result analysis on the base of mathematical models requires involving newest technologies of artificial intelligence to obtain the most effective results. In this paper application of artificial intelligence methods such as neural networks for optimization of drilling process and automation of log curves digitization has been proposed. A hybrid neural network on the base of radial basis network learning by k-means algorithm has demonstrated the highest efficiency for solution of these problems regarding classification and pattern recognition.

1. Introduction

Artificial intelligence represents program and hardware systems modeling such parts of human intellectual activity as analytical thinking [1]. By now thanks to achievements in the field of artificial intelligence a large number of scientific inventions have been made, which significantly simplify human life. Let us mention only a few of them like speech recognition, scanned text recognition, solution of computationally complex problems in short time, and many others. Artificial intelligence systems are always impartial, and results of their work don't depend on so-called "human factor", which allows increasing efficiency of data analysis.

Oil industry relates to areas being characterized by incompleteness of processed information, multicriteriality of problems under consideration and lack of formal approaches to their solution. Neural networks technologies as a kind of artificial intelligence find an application in creation of intellectual oilfields [2], as well as in solution of oilfield development problems such as planning of geological and technical actions [3]. In this paper application of some methods of artificial intelligence to solution of two problems of design in wells construction and oilfields development has been proposed: prediction of troubles in drilling process and automation of log curves digitization.

2. Prediction of troubles in drilling process

The problem of troubles prediction and prevention during wells construction seems to be very important because troubles are accompanied by significant time and material costs for elimination of their consequences. Moreover, troubles can lead to accidents where people die and equipment is destroyed. One way of effective trouble prevention is valid selection of drilling fluids, which is suggested to be carried out on the base of data analysis on earlier drilled wells using artificial neural networks – on of the most widespread tools in the field of artificial intelligence. Artificial neural networks are able to predict situations with unknown type of communications between input and output parameters. It allows finding the best values of model properties minimizing calculation errors in given area (oilfield borders) [4]. Furthermore, neural networks represent a perfect tool for creation of a forecast on the base of minimum information on earlier drilled wells. Whereas traditionally used regression equations or probabilistic models [5] require knowledge of gradients of pressure in a well, characteristics of drilling mud and tripping process and a set of other parameters, which may be not accessible at the moment.

For troubles prediction the authors have been proposed a technique, which allows building forecast on the base of data on spatial location of wells and characteristics of troubles in these wells (depth of the well hole, existence of a trouble and/or its intensity). Thus formalization of the problem of trouble prediction for each object reduces to a problem of identification for a system with several entries and exits on the base of a set of marked examples (already drilled wells of an oilfield).

In solution of forecasting problems the role of a neural network consists in prediction of the system's response on its previous behavior. Knowing values of variable x at the moments, preceding the prediction $x(k-1), x(k-2), \ldots, x(k-N)$, a network develops solution, which will be the most probable value of sequence $\bar{x}(k)$ at the present moment k. For adaptation of weights coefficients of the network actual error of prediction $\varepsilon = x(k) - \bar{x}(k)$ and values of this error in previous time points are used [6]. The purpose of troubles prediction during oil wells construction is forecasting oilfield rocks behavior and tracing tendencies of troubles spread on the base of data on already drilled wells.

A computational experiment on application of various types of neural networks for this problem solution has been carried out. It has been realized by both supervised (multilayer perceptrons, radial basis function neural networks) and unsupervised (self-organizing maps) learning.

A multilayer perceptron is the simplest and widely applied kind of neural networks. It consists of multiple layers, each of them being formed by neurons and each layer being fully connected to the next one by means of weights system (Fig. 1).

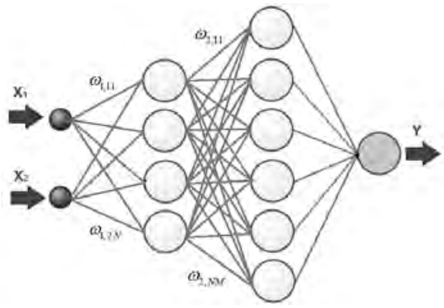

Figure 1. Multilayer perceptron.

Mathematically, each neuron represents the weighted adder, a single output of which is defined by its inputs and a matrix of weights as a result of sigmoid activation function application.

An important property of any neural network is its ability of learning. The learning process is a procedure of customizing weights and thresholds for the purpose of reducing difference between target and obtained vectors at the output. Perceptron learning is carried out on the base of backpropagation algorithm [4].

Radial basis function neural network (RBFNN) is a network having two-layer structure, where the hidden layer carries out nonlinear mapping that uses radial basic functions as activation functions (Fig. 2).

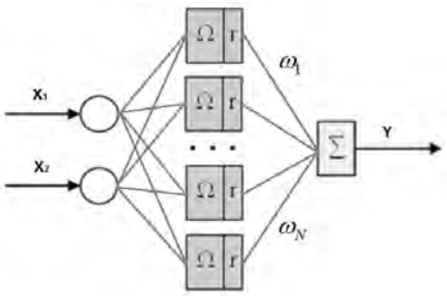

Figure 2. Radial basis function neural network.

RBFNN is similar to multilayer perceptron by the structure, but it differs by the type of activation function. Besides, RBFNN is being teached more quickly in comparison with backpropagation algorithm and don't encounter difficulties with local minimums. But RBFNN learning needs more computer memory and works more slowly because of bigger set of elements (number of neurons in the hidden layer usually corresponds to the number of training set elements). This problem may be eliminated by preliminary modification of RBFNN parameters, i.e. by k-means algorithm.

A self-organizing map represents a two-dimensional network applied to the space of input data. This network changes its form in such a way as to approach input data more precisely (Fig. 3).

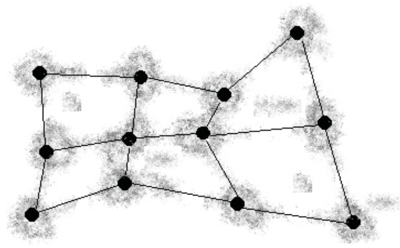

Figure 3. Self-organizing map.

Each point of data is associated with the nearest node of network. Network learning which represents finding location of network nodes, is carried out on the base winner-take-all principle. Advantage of self-organizing maps is that such network learns to understand the structure of data, but it is more available for solution of clustering problems than classification.

For selection of the most effective neural network, a model example has been designed. It includes 30 points of four colors as input data (Fig. 4). Computational experiment on color identification for each point of the plane realizing application of chosen types of neural networks has been carried out.

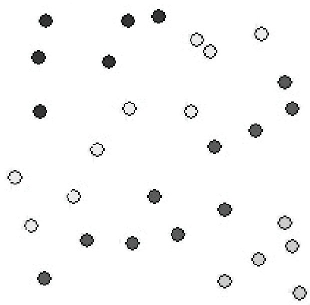

Figure 4. Model example for classification problem.

Since any neural network represents a set of nodes (neurons) connected with each other, the object of computational experiment is the structural and parametrical identification of the most effective neural network that is selection of its kind and parameters of neurons. The most effective neural network (by the ratio of accuracy and computing speed) is a hybrid one, where a radial basis function neural network is learned with the use of k-means algorithm (Table 1, Fig. 5). It should be noted that effective solution of prediction problem is possible only if the neural network is learned on representative sample.

Table 1. Computational experiment for solution of classification problem

N	Type of a neural network	Neural network parameters	Run time
1	Multilayer perceptron	1 hidden layer, 4 neurons	11 min
2	Multilayer perceptron	2 hidden layers, 4 and 6 neurons	8 min
3	Radial basis function neural network	30 neurons	< 1 sec
4	Radial basis function neural network with k-means algorithm	8 neurons	< 1 sec
5	Self-organizing map	300 neurons	16 sec

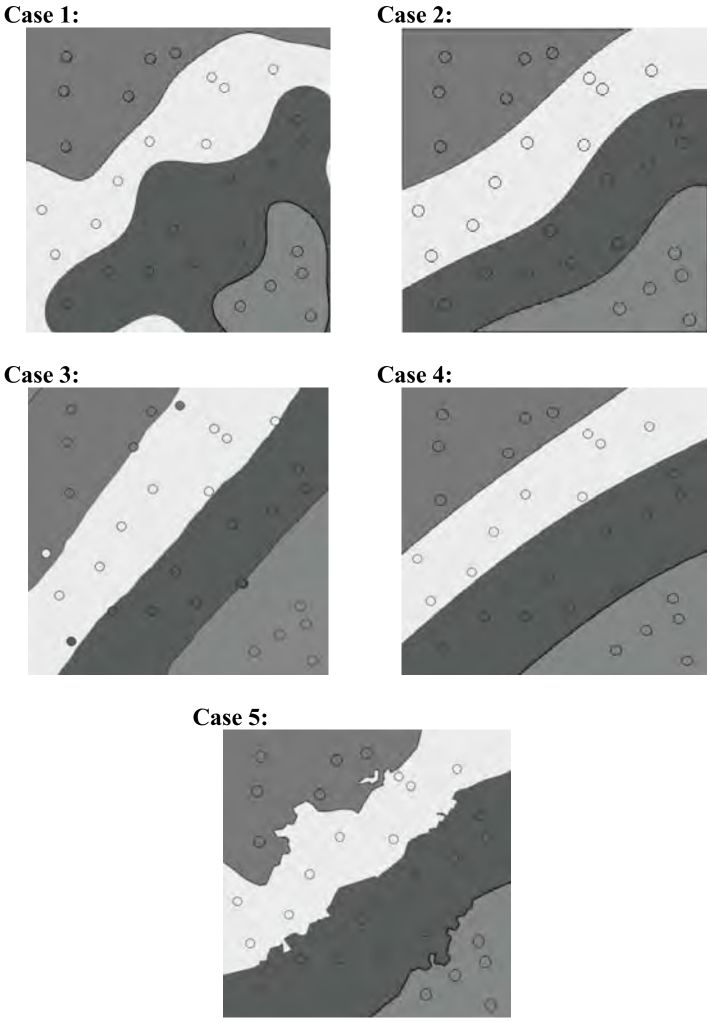

Figure 5. Results of networks learning for cases 1-5.

The algorithm of RBFNN learning is presented in Fig. 6.

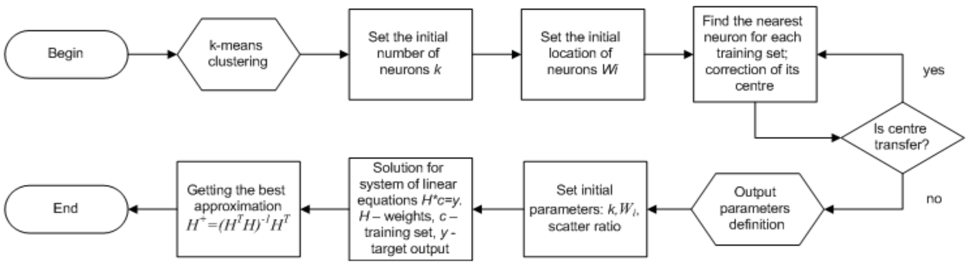

Figure 6. Learning algorithm of radial basis function neural network.

On the base of designed neural network a clustered map of existence and intensity of troubles on an oilfield is built automatically. This map allows tracing tendencies of troubles spread for each stratigrafical object within the oilfield (Fig. 7).

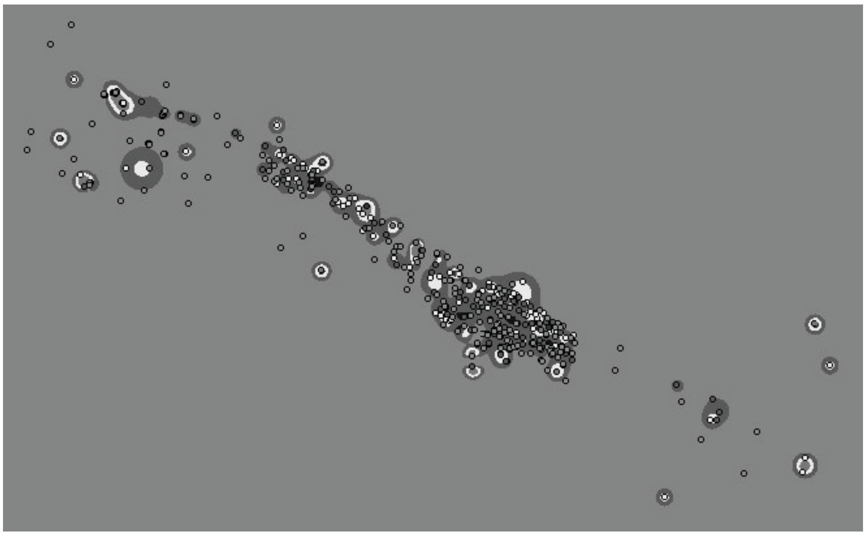

Figure 7. Clusterized oilfield map (dots are already drilled wells).

On the base of this forecast, recommendations on type and properties of drilling mud and parameters of technological operations during new well construction are being issued.

Software testing has been conducted for some oilfields of Bashkortostan Republic [7]. For the purpose of comparing probable values with real data computation for already drilled wells has been carried out. Results agree in 80% cases. Forecast error is caused by influence on troubles appearance of various technology factors (drilling fluid property, parameters of round-trip operations and others), and is compensated by forecast immediacy on the base of minim input data. Now developed software is being used for designing projects on wells construction at JSOC Bashneft oilfields.

3. Automation of log curves digitization

One more important problem, for which decision methods of artificial intelligence seem to be effective, is the problem of digitization of well-logging measurement curves. Relevance of this problem is caused by large volume of archival log curves on earlier drilled wells in paper, which are accumulated at many design institutes of oil companies, particularly, in BashNIPIneft LLC. Meanwhile, taking into account larger number of wells in an oilfield on which well survey data are provided, allows building geological models and to make calculations of hydrocarbons stocks more precisely.

Existing software for well survey data processing allows carrying out digitization of graphically presented data in part-manual mode. It seems to be ineffective because of influence of a human factor and necessity of processing large volume of information. Therefore, the problem of software development that allows carrying out correct digitization of log curves in automatic mode has been set.

Archival log curves are presented by two kinds: software-based obtained curves (for which basic data are lost) and analog charts in paper carriers. For program recognition of graphical log curves of the first kind, pixel by pixel reading of the bitmap image has been realized. Problems arising are presented in Fig. 8, they are: various tracing of curves (dotted lines, thick lines, etc.), coincidence of colors for various curves (color duplication), existence of signs and superfluous colors. These problems may be solved without aid of neural networks, by means of interpolation and normalization of obtained images.

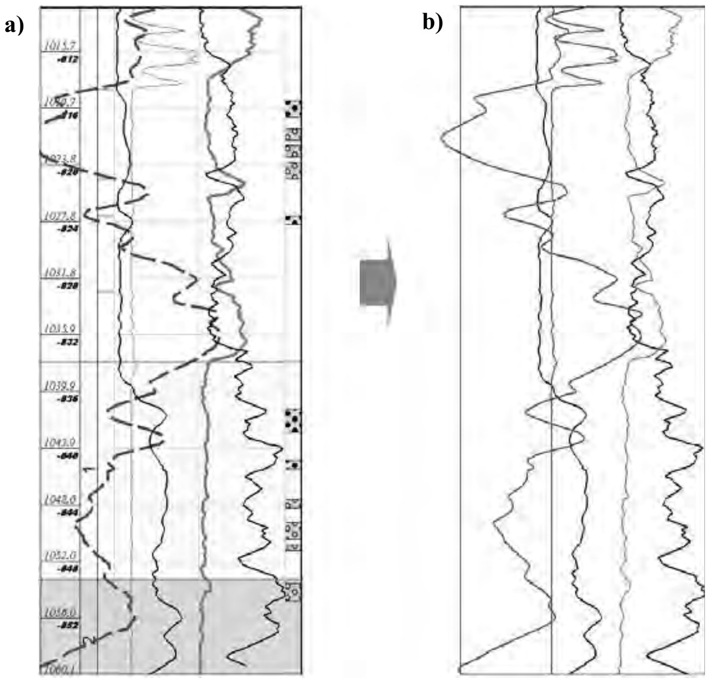

Figure 8. Log curves:

a) Initial data; b) Processed curves.

When switching to recognition of analog curves on paper carriers, typical problems are as follows: necessity of hand-written text reading and heterogeneity of scale on depth, arising during scanning of papers. The formal problem statement is reduced to a problem of objects recognition: it is required to construct an algorithm which decides for any entrance object (not necessarily belonging to the learning set), which class does this object belong to [8]. Figures 9-10 demonstrate recognition of a number “2” in different cases.

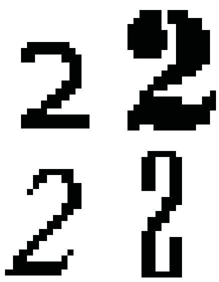

Figure 9. Different variants of number “2” writing.

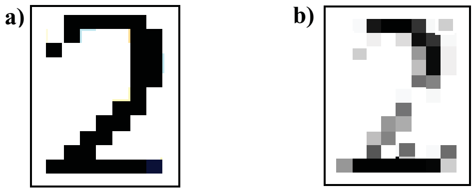

Figure 10. Formalized image of number “2”:

a) without distortions; b) with distortions.

At the moment debugging of considered problem solution on the base of earlier described hybrid artificial neural network is being carried out. Developed algorithms allow recognizing unambiguously well survey data in paper, and this, in its turn, increases accuracy of models constructed on the base of these data.

4. Concluding remarks

Obtained results allow increasing calculation efficiency and reducing influence of a human factor during design of well construction and field development. Generally, methods of artificial intelligence allow creating applied neural systems, owing to which structural and parametrical identification of objects has been realized. It allows solving problems of classification and images recognition in oil and gas industry efficiently. Thus, the prospect of IT infrastructure development in oil and gas industry is connected first of all with automation of work in all directions of oil and gas development, production, transportation and refining on the base of intelligence systems.

References

1. George F. Luger: *Artificial Intelligence: Structures and Strategies for Complex Problem Solving.* Moscow, Williams, 2005 (in Russian).
2. Egorov A.A.: *The part of intelligence systems in oil and gas industry: conditions and prospects.* Automation and IT in oil and gas industry (http://www.avite.ru/ngk/stati/rol-intellektualnyih-sistem-v-neftegazovoy-otrasli-predposyilki-i-perspektivyi.html) (in Russian).
3. Glova V.I., Anikin I.V., Shagiakhmetov M.R.: Systems of fuzzy modeling for problems of increasing oil production solving. *Bulletin of KSTU named after A.N. Tupolev,* no.3, 2001, p. 59-61 (in Russian).
4. Haykin S.: *Neural Networks: A Comprehensive Foundation.* Pearson Education, 2005.
5. Yasov V.G., Myslyuk M.A.: *Prediction of loss during fractured reservoirs drilling*. Moscow, VNIIOENG, 1982 (in Russian).
6. Gorban A.N.: The generalized approximating theorem and computational power of neural networks. *Siberian journal of computing mathematic*s, vol.1, no.1, 1998, p.12-24 (in Russian).
7. Lind Yu.B., Mulyukov R.A., Kabirova A.R., Murzagalin A.R.: Online prediction of troubles in drilling process. *Oil industry*, no.2, 2013, p.55-57 (in Russian).
8. Merkov A.B.: *Basic methods of images recognition in paper.* (http://www.recognition.mccme.ru/pub/RecognitionLab.html/methods.html) (in Russian).

Yulia Lind, Ph.D.: BashNIPIneft LTD, Lenina St. 86/1, 450055 Ufa, Russia (LindUB@bashneft.ru), the author gave a presentation of this paper during one of the conference sessions.

Jan Awrejcewicz, Professor: Technical University of Lodz, Department of Automation and Biomechanics, 1/15 Stefanowskiego St. 90-924 Lodz, Poland (Jan.Awrejcewicz@loewe-adria.de).

Aigul Kabirova, M.Sc (Ph.D. student): Institute of Petrochemistry and Catalysis of RAS, Laboratory of Mathematical Chemistry, prospect Oktyabrya 141, 450075 Ufa, Russia (arish-07@mail.ru).

Azamat Murzagalin, B.Sc. student: Bashkir State University, Department of Mathematics and Information Technology, Z. Validi St. 32, 450076 Ufa, Russia (i.am.em@inbox.ru).

Anna Khashper, B.Sc. student: Bashkir State University, Department of Mathematics and Information Technology, Z. Validi St. 32, 4500076 Ufa, Russia (bella_anna_tw@mail.ru).