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DOI: 10.25045/jpit.v09.i2.05

PROSPECTS OF INTELLIGENT OIL AND GAS FIELDS

The article deals with the application of intelligent technologies in oil and gas fields for solving various problems. These include the intellectualization of analysis of large amounts of data collected from oil and gas fields, the intellectualization of the drilling process, the forecast of reserves and the optimization of oil and gas production activity, the optimization of the location and management of oil and gas fields, etc. At the same time, intellectualization of oil and gas fields is impossible without the use of information technology. The intellectualization of oil and gas fields leads to an increase in the effectiveness of remote monitoring and management of oil and gas production, the accuracy of geophysical research, safety, and the reduction of structural costs and the continued competitiveness of oil companies.

Keywords: *oil and gas fields, artificial intelligence, intelligent technologies, information technologies, exploration and exploitation of oil and gas fields, forecast of reserves and optimization of oil and gas production activity, drilling process intellectualization.*

Introduction

Today, information technology (IT) is widely used in various industries. The oil and gas industry is characterized by the most intensive use of IT. The use of IT enables the intellectualization of oil and gas fields, which increases the effectiveness of remote control and management of oil and gas production, the accuracy of geophysical research, safety, etc. Intellectualization also plays an important role in reducing structural costs and ensuring the competitiveness of oil companies. Therefore, giant oil companies such as British Petroleum, Shell, Chevron, etc. focus on the intellectualization of oil and gas fields [1].

The intelligent field is a system for automatic management of operations of oil and gas production, which provides uninterrupted optimization of integrated field model and production management model [2]. The term "intelligent field" describes a method that achieves the maximum total production during the entire lifecycle of the field by continuously optimizing the operation of all its components: wells, beds, pipelines and various field facilities [3].

There are some main factors that impose the intellectualization of oil and gas fields. First, this is an increased demand for oil and gas, despite the development of alternative energy carriers. Secondly, the development of IT, for example, network technologies, such as cloud computing, which enables processing, storing and transferring large amounts of data. Cloud computing is used in various industrial areas, including the oil and gas industry [4, 5]. Thirdly, the need for reducing the share of manual labor, i.e., the introduction of automated systems can lead to minimizing the impact of a shortage of skilled workforce. Fourth, the need for automation of the monitoring of new, remote and geographically problematic areas, where new oil and gas reserves are difficult to be found. Finally, security factor, which is linked to the fact that IT-based intellectualization of oil and gas fields can lead to the minimization of the risks associated with the oilfields safety. However, there may be risks associated with cyber security, i.e., the threats and vulnerabilities associated with cybersecurity are possible, which is a separate subject of study.

Today, the intellectualization of oil and gas fields is developing very rapidly. In the reports provided by Digital Oilfield Market by Solutions (Hardware, Software, and Data Storage Solutions), Processes (Reservoir, Production, Drilling Optimizations), Application (Onshore and Offshore), and the Region - Global Forecast to 2022, the global market of intellectual oil and gas fields is predicted to increase to 27.10 billion USD by 2022 [6].

Due to the obvious advantage of intellectualizing oil and gas fields, large companies started to focus on this area in their research. Various approaches to the intellectualization of oil and gas

fields are described in the literature. They are based on soft-computing and artificial intelligence (neural networks, fuzzy logic and evolutionary computations) [7]. These approaches have played a major role in the intellectualization of oil and gas fields in recent years.

The goal of this paper is to analyze the challenges, methods and prospects of intellectualization of oil and gas fields.

The main challenges of intellectualization of oil and gas fields

A number of complex technical problems arise in the course of exploration and exploitation of oil and gas fields [7]. They are related to the precise determination of soil structure, in-depth studies, accurate description of drilling wells (visualization), detection of malfunctions and determination of their types, prediction and evaluation of surplus pressure, ecology, etc. The development of intellectual oil and gas fields will solve these and other problems.

Intellectual oil and gas fields include infrastructure, telecommunications, reporting and monitoring data, and real time knowledge and data share. These infrastructures enable specialists to make substantiated decisions and take appropriate measures to manage oil and gas fields.

Despite the effectiveness of existing approaches to the intellectualization of oil and gas fields, there are some problems associated with the analysis of a large amount of data continuously received from oil and gas fields, real-time communications, cybersecurity, etc.

The problems of data analysis are related to the fact that a huge amount of data is continuously received from oil and gas fields. These data have to be processed in real time to extract useful information, that is, knowledge. The availability of this knowledge helps to make critical decisions on the management of oil and gas fields. However, extracting useful information from these data is a rather complicated and time-consuming task, which complicates decision-making process. Therefore, the use of new intelligent technologies for data analysis that will enable the efficient and fast analysis of large amounts of data is important. This, in turn, may reduce the time for making decisions and improve their quality.

Problems related to real-time communications occur due to the fact that the intellectualization and integration of telecommunication networks, including the transfer of large amounts of data over wireless networks are complicated. To intellectualize the oil and gas fields, IBM offers to apply the integration concepts of Web services and link them to supportive and integrated service-oriented IT infrastructure [8, 9].

Cyber security in the intellectualization of oil and gas fields is associated with possible threats to information security and vulnerability of IT infrastructure [10, 11].

The methods used for the intellectualization of oil and gas fields

Various artificial intelligence methods are used to solve a wide variety of problems when intellectualizing oil and gas fields [12-14]. These problems include the intellectualization of analysis of large amounts of data collected from oil and gas fields, the intellectualization of drilling process, the forecast of reserves and optimization of oil and gas production, the optimization of the location and management of oil and gas fields, etc. For solving these and other problems, artificial neural networks [15-19], fuzzy logic [20-24], expert systems [25-28], machine learning methods [29], intelligent agents [30, 31], genetic algorithms [32-35], data extracting methods [36, 37], case-based reasoning - CBR [38-40], etc.

Each of these methods enables the development of hybrid systems with additional analysis and search methods using knowledge of the field of research, including empirical data for solving complex problems. Hybrid systems include fuzzy logic, artificial neural networks, genetic algorithms, expert systems and are effective in solving numerous real problems of different areas.

Artificial intelligence (AI), also known as computational intelligence, involves the application of certain areas of science and technology to develop intelligent machines. Characteristic features of AI are: ability to learn by examples, noise resistance and lack of data,

ability to solve nonlinear problems, forecasting and generalization, etc.

The use of AI in oil and gas industry solves many problems, such as development of seismic bed model, determination of permeability characteristics and forecast of bed porosity, determination of pressure-volume-temperature (PVT) of wells, drilling diagnostics, optimization of well production and efficiency, management decisions, etc. AI plays a significant role in the exploration and production of oil and gas, as well as in the management of oil and gas fields. When drilling, AI provides flexibility in choosing the drilling mode, monitoring, forecasting and optimization, which increases the efficiency of oil production.

Artificial neural networks (ANN) are the most widely used and rapidly developing field of AI and represent a flexible mathematical structure capable of describing a complex nonlinear relationship between input and output data sets.

The architecture of ANN models is based on biological neural system and consists of many processing elements called neurons and working in parallel. Each neuron is interconnected, and these connections have certain weights, which are the data used by network to solve a specific task. ANN has the ability to imitate the human properties of solving problems that are difficult to imitate using logical and analytical methods of expert systems. With the help of ANN it is possible to simulate control processes, condition monitoring, sensor monitoring, fault diagnosis of various systems, etc. One of the main advantages of ANN over other modeling methods is the ability to train and simulate complex nonlinear processes. ANNs are trained based on the data obtained from the system and can solve optimization tasks, pattern recognition, clustering, function approximation, time series analysis, forecasting, etc.

Various paradigms are used to train ANN, namely unsupervised and supervised training. Each of these paradigms corresponds to a specific abstract training task.

Today ANN is widely used to solve many problems in the oil industry. For example, ANNs are used to forecast oil [17] and gas reserves and to optimize oil and gas production in fields [18], when simulating drilling and oil and gas production [19], etc.

Fuzzy logic was suggested by Lotfi A. Zadeh in 1965, the main idea of which is based on the concept of a fuzzy set with the function of elements belonging to a set that takes any values within the interval [0, 1]. As a result, unlike classical logic, various logical operations on fuzzy sets are introduced and the concept of a "linguistic variable" is formulated, in which fuzzy sets are represented as values.

Fuzzy logic is used in the areas associated with oil and gas production technology. These areas include physics of oil reservoir [20, 21], determination of oil and gas reserves [22], increasing oil and gas production [23], decision-making process [26], etc.

Expert systems are AI tools which store and use expert knowledge, including the methods and rules for decision making. Expert system can be defined as an interactive computer decision tool that imitates the thinking behavior of a human specialist to solve complex problems in a certain field. The need to use expert systems is associated with limitations in expertise, working memory, lack of capacity for sufficient analysis of significant data, etc.

In oil and gas industry, expert systems can be used to solve a variety of tasks, ranging from oil and gas field management [25] to analysis of data obtained from oil and gas fields [27], etc.

An intelligent agent is a computing system that is capable of performing default and intellectual behavior being located in a dynamic environment. Other intelligent agents may also be located in this environment, and the community of interacting intellectual agents, as a whole, functions as a multitask system. In this case, intelligent agents adapt to the changes in the environment in which they are located.

The use of various intelligent agents for comprehensive reserves modeling on oil reservoirs reduces the data burden on human operator and provides a useful platform. This platform integrates simulation models and economic models to achieve a common stock solution and employees' support for fast and exact analysis [30].

The genetic algorithm is one of AI methods, which is used to model and optimize processes based on the principles of natural evolution and natural selection. To solve optimization problems, inheritance, mutation, selection and crossing-over methods are used. The main feature of the genetic algorithm is using the "crossing" operator, which performs the recombination operation of candidate solutions, the role of which is inspired by crossing in wildlife. This method encodes a possible solution to a particular problem based on a simple chromosomal data structure.

The range of problems to which genetic algorithms are applied is quite wide. They are a good tool for intelligent automation and real-time optimization of the entire oil and gas production process. Genetic algorithms are also used in combination with other intelligent technologies, such as neural networks, expert systems and CBR.

One of the important tasks to be solved when developing oil fields is to increase their oil recovery. Typically, to achieve this, it is necessary to set a number of well parameters, for example, bottom hole pressure in each well, water flow rate during well injection, and so forth. However, one of the biggest problems when setting parameters is the presence of a large number of parameters, which can cause vast difficulties in determining the optimal setting. Therefore, to analyze a large number of parameters or data, special tools are required. Data mining is one of the most popular tools for solving this problem. There are many studies in the literature devoted to the investigation of oil and gas production with the use of data mining [36, 37].

CBR solutions are one of the methods of AI. CBR solves the problems through reusing previous experience, i.e., based of one or more similar problems solved earlier called cases. CBR can be used solely or integrated with other decision methods to achieve more exact results, compensating for the shortcomings of some approaches at the expense of others. CBR enables the use of specific knowledge of specific problem cases previously known. Thus, CBR system requires a fairly large database of cases. To solve a problem, the system starts a search with the description of the problem. Once the best match with the previous case is found, the search ends. A new problem is solved by defining a similar earlier case and reusing it in a new problem case. However, sometimes the modification of problem solution is performed in order to adapt the previous solution to the present case.

CBR is used to reduce exploitation costs when drilling oil wells at the expense of using previous experience gained from previously drilled wells or from the wells that are currently being drilled. Optimization of oil drilling processes can be achieved with the use of CBR [40]. Moreover, CBR can be used to solve the problems related to the exploitation of oil and gas fields, which require a certain description of problem situations.

The papers [41, 43] deal with the construction of an architecture, strategy and decision-making of oil and gas industry using Big Data technologies. Big Data technologies provide key approaches and tools for generating data management systems for oil and gas industry.

Prospects for the intellectualization of oil and gas fields

Due to the high innovative potential of intelligent technologies, the oil and gas field management system, including their information and communication infrastructure have changed significantly. This, in turn, has led to the fact that the paradigms for the development of oil and gas fields has changed. Modern information and communication technologies enable real-time monitoring and control over oil and gas fields remotely and provide responding to changes occurring in them. In [44], the Internet of things (IoT) technology is used to solve the problem of monitoring of intelligent oil and gas fields. In the near future, self-controlled fields and the fields managed by virtual experts groups located in different countries of the world are predicted to be developed [2].

In the study [45], the authors refer to the main trends in the development of intelligent oil and gas fields: creation of an integrated real-time management and decision system for oil and gas field; collection, transfer, processing of geodata sensed from millions of sensors based on unified

standards and data transfer protocols; implementation of environmental, energy- and resource-saving technologies (transport, roads, weather, resources - metal, water, air, soil, reagents, spare parts, equipment), real time exploitation of oil and gas fields; transfer of management of real time exploitation of oil field in real time; transition to fully automated and deserted technologies in new offshore oil and gas fields, etc.

The development of intelligent oil and gas fields enables mining companies to advance remote areas and descend to more significant sea depths, including under Arctic ice.

Conclusion

The paper revealed some of the complex tasks associated with the exploration and exploitation of oil and gas fields to be solved. However, solution of these problems through traditional methods is inefficient, which leads to a decrease in the efficiency of development of oil and gas fields.

One of the effective approaches to the problem solution is the intellectualization of oil and gas fields. The current development of information and intellectual technologies makes it possible to solve it quite successfully.

For the intellectualization of oil and gas fields, a variety of intelligent technologies are used, such as artificial neural networks, fuzzy logic, expert systems, machine learning, intelligent agents, genetic algorithms, data mining methods, case-based reasoning, etc.

The use of intelligent technologies in oil and gas industry has led to the emergence of a new paradigm for the development of oil and gas fields and allows solving the problems as the effective analysis of large amounts of data sensed from oil and gas fields, the intellectualization of drilling process, the stock forecast and the optimization of oil and gas production, the optimization of location and management of oil and gas fields, etc.

Acknowledgment

This work was carried out with the financial support of the Scientific Foundation of SOCAR (State Oil Company of the Republic of Azerbaijan).

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