



- (51) International Patent Classification:
E21B 47/26 (2012.01) *G06F 17/50* (2006.01)
- (21) International Application Number:
PCT/RU2016/000182
- (22) International Filing Date:
31 March 2016 (31.03.2016)
- (25) Filing Language: English
- (26) Publication Language: English
- (71) Applicant (for US only): **SCHLUMBERGER TECHNOLOGY CORPORATION** [US/US]; 300 Schlumberger Drive, Texas, Sugar Land, 77478 (US).
- (71) Applicant (for CA only): **SCHLUMBERGER CANADA LIMITED** [CA/CA]; 125-9 Avenue SE, Alberta, Calgary, T2G 0P6 (CA).
- (71) Applicant (for FR only): **SERVICES PETROLIERS SCHLUMBERGER** [FR/FR]; 42 rue Saint Dominique, 75007 Paris (FR).
- (71) Applicant (for all designated States except CA, FR, US): **SCHLUMBERGER TECHNOLOGY B.V.** [NL/NL]; Parkstraat 83-89m, NL-2514 JG The Hague (NL).
- (72) Inventor; and
- (71) Applicant (for US only): **SPESIVTSEV, Pavel Evgenievich** [RU/RU]; Kastanaevskaya str., 43-5-41, Moscow, 121108 (RU).
- (74) Agent: **ARKHIPOVA, Vera Nikolaevna**; TECHNOLOGY COMPANY SCHLUMBERGER, ul. Pudovkina, 13, Moscow, 119285 (RU).
- (81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.
- (84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).
- Published:
— with international search report (Art. 21(3))

(54) Title: METHOD FOR PREDICTING PERFORMANCE OF A WELL PENETRATING

(57) Abstract: The method includes storing a well data comprising historical well parameters and historical well performance characteristics obtained from a plurality of operating wells in a knowledge database in a memory storage and performing, by a cognitive system, an analysis of said well data, wherein said analysis produces relationships between said historical well parameters and said historical well performance characteristics. Then, the method includes inputting, into the cognitive system, new well parameters characterizing an underground hydrocarbon bearing formation and a new well penetrating the formation. Based on the produced relationships the cognitive system predicts performance characteristics of said new well and a corresponding uncertainty of the prediction. The method may also include planning at least one strategy of a group consisting of well location, drilling and completion strategies using the predicted performance characteristics, and implementing the planned strategies using hydrocarbon bearing formation equipment.



METHOD FOR PREDICTING PERFORMANCE OF A WELL PENETRATING

Field of the invention

The present invention is related to the field of software technology and data analysis in the petroleum industry. More specifically, the present techniques are directed to systems and methods for predicting the future performance of new or planned oil and gas wells and determining parameters for the location, drilling and completion of a well based on the predicted performance of the well.

Background of the invention

The prediction of the future performance of the new or planned well is important for making the economical evaluation of the well. If the poor production performance is predicted, then such parameters as the well location, drilling and completion strategies should be improved based on the predicted performance of the well. Once the parameters are changed, they can be used to get the updated production prediction using the presented invention to estimate if the changes lead to the positive impact on the economical parameters. Hence, the production predictions provided by the present invention allow to solve the production optimization problem for new or

planned wells. Predicting performance of the new wells is also critical for the large scale field development planning and for the financial forecasts of the field development projects. In the present invention, the prediction is based on the past observations and is done without performing numerical simulations that are usually CPU-time expensive. Hence, the predictions are provided significantly faster than using the traditional simulation-based approaches.

Traditionally, to predict the well production performance the numerical simulations are carried out. In this approach, the data available for the studied well (e.g. seismic, well logging, core analysis data etc.) is pre-processed and entered in the numerical simulator to create the mathematical model of the well connected with the reservoir and perform the hydrodynamic modeling in this system (see Petroleum Reservoir Simulation by Aziz, K., Applied Science Publishers, 497 p., 1979, pages 412-414). This approach has limitations. First, the mathematical models in these simulators are based on the laws of physics that often require closure relations obtained from experiment. As experiments are usually carried out for the limited ranges of the problem parameters (e.g. pressures and temperatures), the predictivity of numerical simulators is restricted. Second, the numerical simulations are time consuming.

Summary of the invention

Disclosed is a method for predicting performance of a well penetrating an underground hydrocarbon bearing formation which doesn't require numerical simulations and includes machine learning and pattern recognition

techniques implemented into the computer system and performed over all available historical data. The method includes storing a well data comprising historical well parameters and historical well performance characteristics obtained from a plurality of operating wells in a knowledge database in a memory storage and performing, by a cognitive system, an analysis of said well data, wherein said analysis produces relationships between said historical well parameters and said historical well performance characteristics. Then, the method includes inputting, into the cognitive system, new well parameters characterizing an underground hydrocarbon bearing formation and a new well penetrating the formation and predicting, by the cognitive system, performance characteristics of said new well and a corresponding uncertainty of the prediction based on the produced relationships. The method may also include planning at least one strategy of a group consisting of well location, drilling and completion strategies using the predicted performance characteristics, and implementing the planned strategies using hydrocarbon bearing formation equipment.

Brief description of the drawings

The disclosure is illustrated by drawings where:

Fig. 1 shows a flowchart in accordance with one or more embodiments of the disclosure;

Fig. 2 illustrates a computing system in accordance with one or more embodiments;

Fig.3 shows an example of the method and a computing system in accordance with one embodiment.

Detailed description of the invention

Reference will now be made in detail to embodiments, examples of which are illustrated in the accompanying figures.

The proposed invention provides the solution of the petroleum engineering problem without carrying out the time consuming numerical simulations.

Fig. 1 shows a flowchart in accordance with one or more embodiments.

The disclosed method comprises storing by a computing system in a knowledge database in tangible memory storage a well data comprising historical well parameters and historical well performance characteristics obtained from a plurality of operating wells drilled in hydrocarbon bearing formations (Block 1).

According to one embodiment of the disclosure the well data stored in the knowledge database additionally comprises information from publications such as results of studies on optimal strategies of well drilling, completion, and production.

According to another embodiment of the disclosure the well data stored in the knowledge database additionally comprises results of numerical simulations executed beforehand and providing the relations between at least part of the new well parameters and a simulated well performance. It is especially important in situations where the historical well parameters and the

historical well performance characteristics are not enough or missing in the knowledge database.

In accordance with one more embodiment of the disclosure the historical well parameters obtained from the plurality of operating wells comprise at least one of a group consisting of petrophysical properties of the hydrocarbon bearing formations, fluid properties, configuration of the wells.

In accordance with another embodiment of the disclosure the historical well performance characteristics obtained from the plurality of operating wells comprise at least one of a group consisting of flowrates of hydrocarbons, peak surface rates, pressure and temperature distribution in the wells and hydrocarbon bearing formations, duration of well cleanup or flowback.

The information from different sources can be assigned a relevance factor that will determine the overall contribution of this source to the prediction.

In Block 2, an analysis of said well data stored in the knowledge database is performed by a cognitive system of the computing system, wherein said analysis produces relationships between said historical well parameters and said historical well performance characteristics.

The cognitive system can have a form of hardware with the pre-installed software or a software only distributed for installation on commonly used hardware with the installed commonly used operation systems. The cognitive system analyses the available information and establishes links and relations between the input historical well parameters of the problem (such as petrophysical properties of the underground hydrocarbon bearing formation, fluid properties, configuration of wells to deliver the hydrocarbons to surface)

and the output parameters of the problem that is the historical performance of wells (e.g. surface flowrates of oil, water, and gas, peak surface rates, pressure and temperature distribution in the wells and hydrocarbon bearing formation, duration of well cleanup or flowback). The cognitive system performs the data processing and analytics, and pattern recognition to improve the predictability of the well performance.

The historical well parameters can be combined in metrics containing numbers thus representing digital fingerprints of the historical wells. The digital fingerprinting allows to convert the vast amounts of data in form of spatially and temporarily distributed arrays of parameters to a reduced and more compact form containing smaller amount of numbers. For example, instead of comparing two spatial logs of absolute permeability for the new and historical wells one will have to compare the two average values for the new and historical well over the measured interval. The digital fingerprinting allows to execute the rapid search over the historical wells by comparison and analysis of the finger prints of the historical and new wells. The digital fingerprint (metrics) can contain such values, as mean value of permeability, density of fluids at standard conditions, and other parameters relevant to the domain of oil and gas.

In Block 3, new well parameters characterizing an underground hydrocarbon bearing formation and a new well penetrating the formation are submitted by a user into the cognitive system of the computing system via an interface.

In accordance with one embodiment of the disclosure the new well parameters characterizing the underground hydrocarbon bearing formation

and the new well penetrating the formation may comprise at least one of a group consisting of petrophysical properties of the hydrocarbon bearing formations, fluid properties, configuration of the new well.

In Block 4, the comparison of the parameters of the new well with the historical well parameters is performed by the cognitive system using data analytics techniques such as a machine learning or a pattern recognition.

In Block 5, performance characteristics of said new well and a corresponding uncertainty of the prediction based on the produced relationships are predicted using the computing system.

For the given input parameters of the new well provided the cognitive system of the computing system predicts the output parameters - performance characteristics of said new well and provides the associated uncertainties.

The predicted performance characteristics of the new well can comprise a hydrocarbon production from the well, a flow rate of a particular hydrocarbon from the well, pressure and temperature distribution in said new well and in said hydrocarbon bearing formation, a duration of the well cleanup or flowback, cumulative values of surface rates and peak values of the surface rates of hydrocarbons.

Workflow may also include planning well location, drilling and completion strategies using the predicted performance characteristics (Block 6), and implementing the planned strategies using hydrocarbon bearing formation equipment (Block 7).

The computing system may be of virtually any type regardless of the platform being used. For example, the computing system may be one or more

mobile devices (e.g., laptop computer, smartphone, smartwatch, personal digital assistant, tablet computer, or other mobile device), desktop computers, servers, blades in a server chassis, or any other type of computing device or devices that includes at least the minimum processing power, memory, and input and output device(s) to perform one or more embodiments of the invention.

Figure 2 shows an example of the computing system in accordance with some embodiments. The computing system may include a cognitive system 8 comprising a processor to perform the data analytics and generation of predictions, a memory storage 9 and a user interface 10.

The cognitive system 8 simulates the process of human thought using a numerical model. Cognitive systems use data mining, machine learning, pattern recognition and language processing techniques to perform the analysis of data (see *Smart Machines: IBM's Watson and the Era of Cognitive Computing* by John E. Kelly III, Columbia Business School Publishing, 160 p., 2013 for more details on the cognitive systems). These features enable the cognitive systems to efficiently perform the analytics on the data available in the petroleum industry and provide data driven predictions for the new or planned wells.

The computing system comprises the memory storage 9 (e.g., random access memory (RAM), cache memory, flash memory, etc.), one or more storage device(s) (e.g., a hard disk, an optical drive such as a compact disk (CD) drive or digital versatile disk (DVD) drive, a flash memory stick, etc.), and numerous other elements and functionalities.

Software instructions in the form of computer readable program code to perform one or more embodiments may be stored, in whole or in part, temporarily or permanently, on a non-transitory computer readable medium such as a CD, DVD, storage device, a diskette, a tape, flash memory, physical memory, or any other computer readable storage medium. Specifically, the software instructions may correspond to computer readable program code that when executed by a processor(s), is configured to perform one or more embodiments of the method.

The computing system also comprises a user interface 10. The conventional user interface provides a means for one or more users to provide information to the system and retrieve information therefrom. Illustratively, the interface can be Windows-based graphical user interface (GUI) including a keyboard, a mouse and a display.

Further, one or more elements of the aforementioned computing system may be located at a remote location and connected to the other elements over a network. Further, embodiments may be implemented on a distributed system having multiple nodes, where each portion of an embodiment may be located on a different node within the distributed system. In one or more embodiments, the node corresponds to a distinct computing device. Alternatively, the node may correspond to a computer processor with associated physical memory or to a computer processor or micro-core of a computer processor with shared memory and/or resources.

Figure 3 shows an example computing system in accordance with some embodiments of the disclosure. Consider horizontal wells after a multi-stage hydraulic fracturing treatment. In general, such wells share certain similarity

in the design. They consist of a vertical segment connected with a horizontal part with fractures distributed along the horizontal interval. To illustrate the idea of present invention, consider the idealized situation where the complete set of data for several wells is available in the memory storage 2. For simplicity, assume that these wells have absolutely the same parameters but a length of the horizontal part and the number of inflow points (fractures). The number of fractures is considered to be equally distributed and proportional to the length of the horizontal part. The historical data is available for several wells with the horizontal part length from 2000 m to 5000 m. After performing the data analysis, the cognitive system 8 learns that the gas flowrate during the initial production stage is linearly proportional to the length of the horizontal interval given that the inflow points are equally distributed. The data available for the cognitive system 8 include the following:

- For the well with the horizontal part length 2000 m the gas flowrate during the initial production is 26000 m³/day
- For the well with the horizontal part length 5000 m the gas flowrate during the initial production is 62000 m³/day

A new well with the horizontal part length of 3000 m long is planned for drilling. Before the drilling starts, the future performance of this well should be evaluated. The information characterizing the new well is provided to the cognitive system 8 through an interface 10.

In this idealistic case, the cognitive system 8 will predict the performance of 38000 m³/day after the well flowback by the simple linear interpolation inside of the known range of parameters. Hence, the proposed

system will yield the output based on the past data analysis without performing numerical simulations. The process is schematically illustrated in Fig. 3.

In the real application, the forecast will be associated with uncertainties related to the differences in configuration between the analyzed and predicted wells. The cognitive system will also apply the advanced data analysis algorithms to process the differences in configuration between the predicted wells and wells with available data. This analysis will be complemented with the information available from other sources such as publications (e.g. full academic journal papers, technical reports, books, etc).

While the above has been described with respect to a limited number of embodiments, those skilled in the art, having benefit of this disclosure, will appreciate that other embodiments can be devised which do not depart from the scope as disclosed herein. Accordingly, the scope should be limited by the attached claims.

Claims

1. A computer-implemented method for predicting performance of a well penetrating an underground hydrocarbon bearing formation, the method comprising:

- storing a well data comprising historical well parameters and historical well performance characteristics obtained from a plurality of operating wells in a knowledge database in a memory storage;
- performing, by a cognitive system, an analysis of said well data, wherein said analysis produces relationships between said historical well parameters and said historical well performance characteristics;
- inputting, into the cognitive system, new well parameters characterizing an underground hydrocarbon bearing formation and a new well penetrating the formation; and
- predicting, by the cognitive system, performance characteristics of said new well and a corresponding uncertainty of the prediction based on the produced relationships,
- planning at least one strategy of a group consisting of well location, drilling and completion strategies using the predicted performance characteristics, and

implementing the planned strategies using hydrocarbon bearing formation equipment.

2. The method of claim 1 wherein the historical well parameters obtained from the plurality of operating wells and the new well parameters comprise at least one of a group consisting of petrophysical properties of the hydrocarbon bearing formations, fluid properties, configuration of the wells.

3. The method of claim 1 wherein the historical well performance characteristics obtained from the plurality of operating wells comprise at least one of a group consisting of flowrates of hydrocarbons, peak surface rates, pressure and temperature distribution in the wells and hydrocarbon bearing formations, duration of well cleanup or flowback.
4. The method of claim 1 wherein the predicted performance characteristics of the new well comprise a hydrocarbon production from the well.
5. The method of claim 1 wherein the predicted performance characteristics of said new well comprise a flow rate of a particular hydrocarbon from the well.
6. The method of claim 1 wherein the predicted performance characteristics of said new well comprise pressure and temperature distribution in said new well and in said hydrocarbon bearing formation.
7. The method of claim 1 wherein the predicted performance characteristics of said new well comprise a duration of the well cleanup or flowback.
8. The method of claim 1 wherein the predicted performance characteristics of said new well comprise cumulative values of surface rates and peak values of the surface rates of hydrocarbons.
9. The method of claim 1 further comprising determining, by the computing system, optimized new well parameters for said new well such that a rate of hydrocarbon production of the new well is maximized.
10. The method of claim 1 wherein the well data stored in the knowledge database additionally comprises information from publications.

11. The method of claim 10 wherein the information from publications comprises results of studies on optimal strategies of well drilling, completion, and production.

12. The method of claim 1 wherein the well data stored in the knowledge database additionally comprises results of numerical simulations executed beforehand and providing relations between at least part of the well parameters and a simulated well performance.

13. The method of claim 1 wherein the historical well parameters are combined in metrics containing a combination of numbers thus representing digital fingerprints of the historical wells.

14. The method of claim 13 wherein the digital fingerprints comprise a mean value of permeability.

15. The method of claim 13 wherein the digital fingerprints comprise densities of fluids at standard conditions.

16. A computing system for predicting performance of a well penetrating an underground hydrocarbon bearing formation, the system comprising:

- a memory storage for storing a knowledge database with an information comprising historical well parameters and historical well performance characteristics from a plurality of operating wells;
- a user interface adapted to receive user inputs for new well parameters characterizing an underground hydrocarbon bearing formation and a well penetrating the formation, and

a cognitive system comprising at least one processor coupled to the memory storage and having functionality to execute instructions for:

performing an analysis using said historical well parameters and said historical well performance characteristics, wherein said analysis produces relationships between said historical well parameters and said historical well performance characteristics,

receiving new well parameters characterizing the formation and the well, predicting performance characteristics of the well and a corresponding uncertainty of the prediction and planning at least one strategy of a group consisting of well location, drilling and completion strategies using the predicted performance characteristics.

17. The computing system of claim 16 wherein the processor is additionally configured to execute instructions for determining optimized new well parameters for the well such that a rate of hydrocarbon production of the well is maximized.

1/3

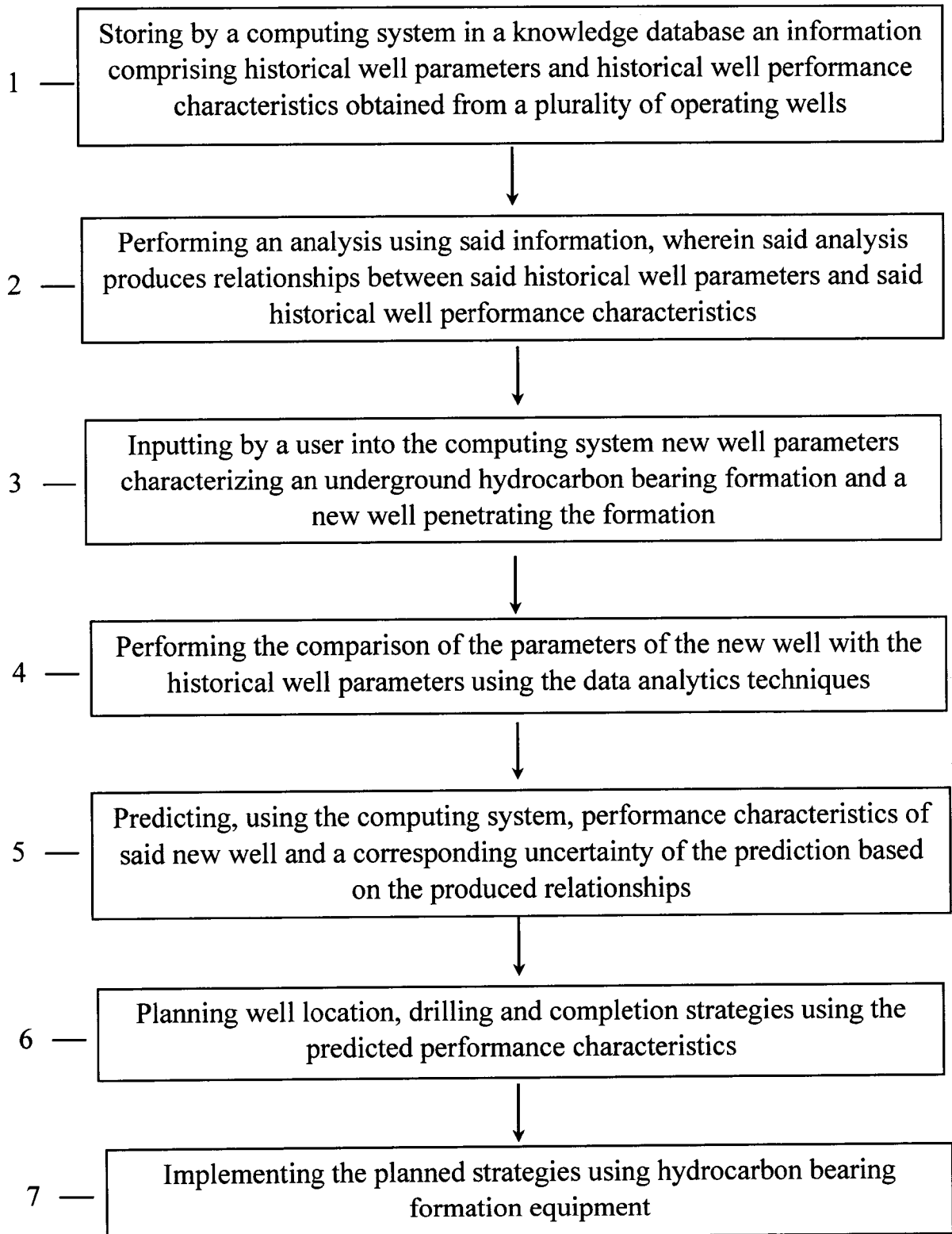


Fig.1

2/3

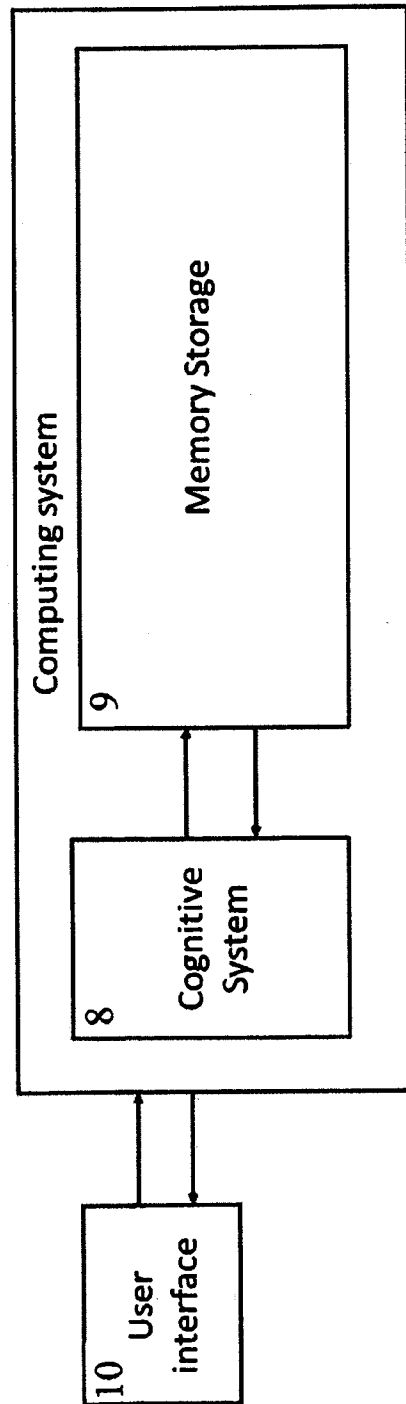


Fig.2

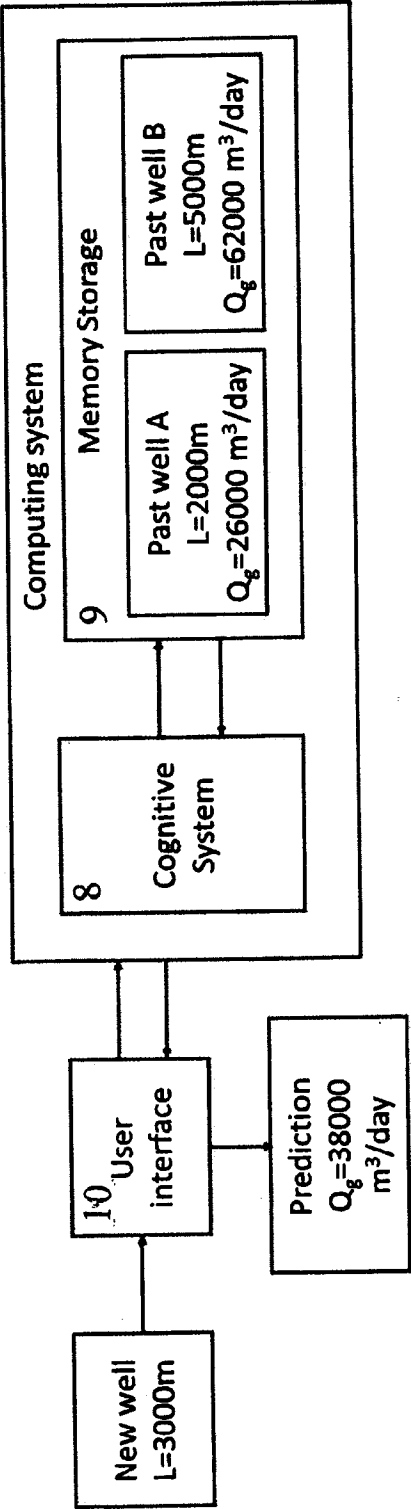


Fig.3

INTERNATIONAL SEARCH REPORT

International application No.

PCT/RU 2016/000182

A. CLASSIFICATION OF SUBJECT MATTER E21B 47/26 (2012.01) G06F 17/50 (2006.01) According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) E21B 43/00, 43/12, 43/16, 47/00, 47/10, 49/00, G01V 99/00, G06F 17/00, 17/50 Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) PatSearch (RUPTO internal), USPTO, PAJ, Esp@cenet, DWPI, EAPATIS, PATENTSCOPE, Information Retrieval System of FIPS		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0881357 B1 (HALLIBURTON ENERGY SERVICES, INC.) 27.10.2004, [0012]-[0014], [0020], [0023]-[0046]	1-17
A	US 2009/0194274 A1 (SCHLUMBERGER TECHNOLOGY CORPORATION) 06.08.2009	1-17
A	US 5251286 A (TEXACO, INC.) 05.10.1993	1-17
A	WO 2009/015031 A1 (SCHLUMBERGER CANADA LIMITED) 29.01.2009	1-17
☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.		
*	Special categories of cited documents:	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family
"A"	document defining the general state of the art which is not considered to be of particular relevance	
"E"	earlier document but published on or after the international filing date	
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	
"O"	document referring to an oral disclosure, use, exhibition or other means	
"P"	document published prior to the international filing date but later than the priority date claimed	
Date of the actual completion of the international search 07 December 2016 (07.12.2016)		Date of mailing of the international search report 29 December 2016 (29.12.2016)
Name and mailing address of the ISA/RU: Federal Institute of Industrial Property, Berezhkovskaya nab., 30-1, Moscow, G-59, GSP-3, Russia, 125993 Facsimile No: (8-495) 531-63-18, (8-499) 243-33-37		Authorized officer A. Grigoryan Telephone No. (499) 240-25-91