Integrated Expert System of Decision Making for Estimating Collector Properties and Oil-and-Gas Saturation of Strata

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Abstract— **This research deals with the problem of developing an integrated expert system for current decision making an adequate selection of field – geophysical parameters and revealing the most significant sub-set for oil and gas deposits of the Apsheron peninsula of Azerbaijan from a multitude of methods of determining collector properties and oil-and-gas saturation of strata. An integrated expert system (IES) is proposed for decision making and analysis of taken decisions as applied to strata of Kyorghyoz-Gyzyltepe-Shongar oil deposit of the Apsheron peninsula.**

Keywords— integrated exspert system; database; knowledge base; rules; facts; statistical analysis

I. INTRODUCTION

As is known, at the end of the seventies of the twentieth century a new conception was adopted in the world of Artficial Intelligence for intellectualization of computer programs by means of providing them with a lot of high-quality special knowledge on a certain application domain. Such computer systems which have become experts in a certain narrow application domain got the name of expert systems (ES) [1]. Analysis of contenporary intelligence information systems (IIS) demonstrates that at the present time an increase is evident for the share of development of integrated expert systems (IES) in the architecture of which along with program component "ES", DBMS, application program packages (APP) etc. are contained widening functional potentialities of the systems [2]. Integrated expert systems are needed in many prduction fields, including the domain of oil-and-gas deposits of the Apsheron peninsula of Azerbaiyan which has been chosen by us as an application domain of the system being developed.

As a result of usage of oil and gas deposits of the Apsheron peninsula of Azerbaiyan Republic for more than a century extensive knowledge is accumulated in collector properties (thickness of collector, porosity, argillization etc.) as well as oil-and-gas saturation of strata (CPOSS). This knowledge was arranged in a definite complex of alternative methods for assesment of CPOSS based on the results of the field-geophysical investigation of wells, in particular, electrical logging and on the results of laboratory analysis of rock samples from wells (a core). The complexity of this variety caused both by the number of methods and the lack of preference criterion does not allow to give preference to some or other alternative methods in the process of decision – making on the estimation of CPOSS for objects of oil-and-gas deposits.

II. CONTENT

The above stated circumstances substantiate the necessity and topicality of the investigations performed in the research which are aimed at developing an integrated expert system of estimation of collector properties and oil-and-gas saturation of strata in oil-and-gas deposits (using Kyorghyoz-Gyzyltepe-Shongar oil-and-gas deposit of the Apsheron peninsula of Azerbaijan as an example).

The startig data for the system being developed are data on the results of employment of a complex of electrical logging methods (spontaneous polarization logging in a well (SP), resistance logging (RL) and partly lateral logging saending (LLS)) on the wells of Kyorghyoz-Gyzyltepe-Shongar oil-and-gas deposit. These are the following data: date of measurement in years; name of horizon; name of block of wells; well number; initial H_{init} and ultimate H_{ult} depths in a well in metros within the limits of which electrical logging was performed (there can be one or more H_{init} and H_{ult} or intervals for each well, i.e. differences between H_{ult} and H_{init}); peak values of drop in spontaneous polarization potentials U_{sp} in mV (according to standard logging results); maximum peak value of drop in spontaneous polarization potentials U_{sp}^{max} in mV (according to standard logging results); value of apparent specific resistance of stratum ρ_a in ohm (according to standard logging results); value of water electric resistance at 20°C ρ_w^{20} in ohm; specific electric resistance of argillaceous stratum (seam) ρ_{arg} in ohm (according to standard logging results, LLS and core analysis); maximum specific electric resistance of pure (without clays) oil-and-gas bearing stratum ρ^{max} in ohm (according to logging LLS results or calculations) [3]. Fig.1 shows structural scheme of the proposed system. The developed IES-CROSS presents a network system using customer / server architecture and consists of components of two types: components working on the computer customer side and components working on the server side. The network structure is dictated by the task itself on this IES. For end outputs the system envisages the use of the results of joint utilization of the described system by a group of independent experts-users working on personal computers of a local network of geophysical laboratory. The initial information of one or more measurements of electrical logging (EL) of wells can be input into the IES from customer computers both for individual wells and in package modes for a group of wells simultaneously in "Data entry or data editing blocks". The input information is stored in the database for subsequent information processing.

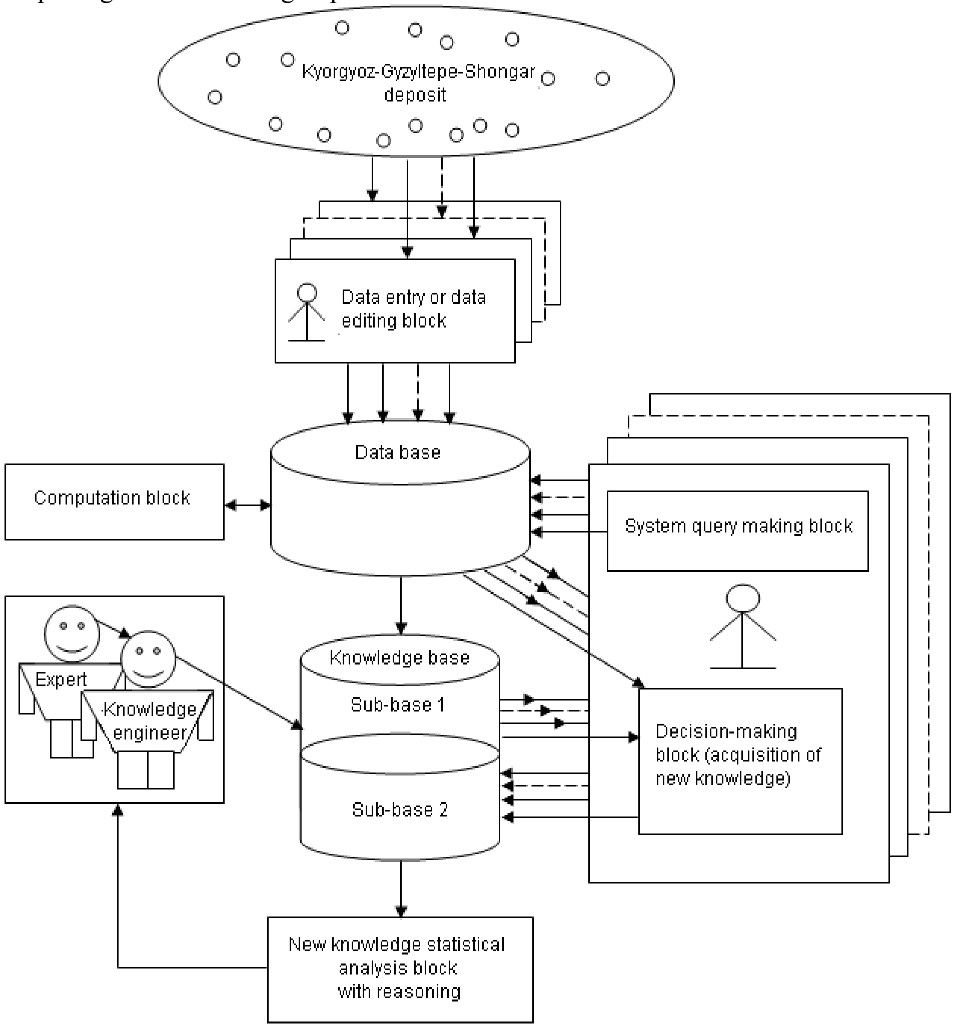

Figure 1. Structural scheme of IES

The following ten substance-objects were singled out for database making-up: horizons, blocks, wells, initial data (measurements), intermediate values (IV), ultimate values (coefficients), total and weighted average values (WAV), average values of total and weighted averages by horizons

(AV_horizon), average values of total and weighted averages by blocks (AV_block) and average block values (AV_blocks) [4].

Users of customer computers can call database from "System query assembly blocks" with the help of SQL expressions SELECT. As criteria for record choice in SELECT-queries users can take a name of horizon, names of horizons and block as well as names of horizon, block and well number.

On the basis of retrieval from "Measurements" table queries by a user, coefficients of argillization, porosity, oil-and-gas saturation and values of effective oil-and-gas saturated thickness of stratum are determined with the help of special methods for the said retrieval in "Computation block".

For representation of expert knowledge we have chosen a logistic model of knowledge representation. Knowledge base is represented as a set of expert rules which are verified on a group of facts (or data). An inverse logical reasoning is applied as the most profitable [5] of the ways of using the rules. Some of the basic heuristic rules are given below:

Rule 1

THEN Select $K_{ogs}1$, K_p1, $h_{ogs}1$ ***IF*** $K_{ogs}1$ is the least from the K_{ogs} set

Where $h_{ogs}1$ – effective oil-and-gas saturated thickness of collector stratum is computed from the formula (see below):

$$h_{og} = H_{ef} * (1 - K_{\arg}) \qquad (1)$$

where H_{ef} – total collector thickness;

K_{arg} - $K_{ogs}1$ – coefficient of argillization determined from α – sp curve (α_{sp}),

$$\alpha_{sp} = U_{sp} / U_{sp}^{\max} \qquad (2)$$

where U_{sp} – actual amplitude of SP-curve as against collector stratum,

U_{sp}^{max} – maximum amplitude value for a given horizon.

K_p1 – porosity coefficient determined from porosity- versus- α_{sp} curve obtained from core data;

$K_{ogs}1$ – oil-and-gas saturation coefficient determined from dependence on α_{sp} on the basis of laboratory analyses of core samples;

Rule 2

THEN Select $K_{ogs}2$, K_p1, $h_{ogs}1$ ***IF*** $K_{ogs}2$ is the least from the K_{ogs} set

Where $K_{ogs}2$ – effective oil-and-gas saturation determined from Archie's formula:

$$K_{ogs} = 1 - (a * \rho_w / K_p^m * \rho_r)^{1/n} \qquad (3)$$

where ρ_w –specific electric resistance of stratal water;

ρ_r – specific electric resistance of rocks;

K_p– porosity coefficient K_p1;

m – rock cementation coefficient;

α and n – empirical constants

Rule 3

THEN Select $K_{ogs}3$, K_p2, $h_{ogs}1$ ***IF*** $K_{ogs}3$ is the least from the K_{ogs} set

Where K_p2 – porosity coefficient determined from S.G. Komarov's versatile formula for porosity:

$$K_p = K_p^{total} - K_p^{\arg} * K_{\arg} \qquad (4)$$

where K_p^{total} –total porosity of collectors determined from cores;

K_p^{arg} – porosity of clays determined from cores;

K_{arg} – $K_{arg}1$ argillization determined from dependence on α_{sp};

$K_{ogs}3$ – oil-and-gas saturation coefficient determined from the formula (3),

where K_p – porosity coefficient K_p2.

Structurally the knowledge base consists of two parts: sub-base1 and sub-base2. The rules elaborated by experts and knowledge engineer together with current facts from database, namely:

- total effective oil-and-gas saturated stratum thicknesses (according to two methods),
- maximum values of argillization coefficients (according to two methods),
- weighted average values of porosity coefficients (according to three methods),
- weighted average values of oil-and-gas saturation coefficients (according to seven methods).

At first preferential decisions are taken in the "Decision-making" blocks with the help of logical reasoning mechanism using rules and facts of knowledge base on the strength of logics of the first-order predicates. These preferential decisions represent vectors (PDV) consisting of three components: oil-and-gas saturation coefficients, porosity coefficients and coefficients of effective oil-and-gas saturated stratum thickness for an object of deposit. As an object of deposit can be selected a horizon, block or well. Afterwards with the participation of users – experts of medium qualification – final decision vectors (FDV) are assumed which can coincide with PDV or differ in some or other aspects from the said PDV. FDV are accompanied by explanations – these explanations can suppose intuition among other things as well. The "Decision-making" blocks also act as blocks of new knowledge acquisition. The assumed final-decision vectors being essentially new knowledge (facts), make the contents of the Sub-base2 in the knowledge base.

With the aim of revealing the most significant subset of methods for CROSS determination we have stated the task of finding the frequency of employment of specific decision vectors (or rules – in the final analysis, alternative methods) in the process of users' work with program implementation of IES. In each act of making final decision statistical frequencies of user's (users') call before the given moment of time to such objects of deposit as horizon, block or well are calculated in "Decision-making (acquisition of new knowledge)" blocks as the ratio between the amount of calls to this object and the total amount of calls to objects of this type. FDV from each user of a computer with installed IES-CROSS system are accumulated in the sub-base2 of the knowledge base forming new knowledge. This knowledge is also analyzed in "Block of statistical analysis of new knowledge with reasoning" in real-time mode. The aim is revealing the most employed rules of the knowledge base – the most adequate subset of methods for investigation into collector properties and oil-and-gas saturation of strata. For analysis, statistical frequencies of FDV for each user are calculated as the ratio between the amount of assumed specific decision vectors to the total amount of taken decisions.

In the process of using a prototype IES-CROSS version at the "Neftgaz" Research-and-Design Institute of SOCAR taking Kyorghyoz-Gyzyltepe-Shongar deposit as an example, during the first quarter of 2010 [6] statistical frequencies of FDV were determined for the deposit on the whole, for horizons, blocks and wells from each expert-user which are displayed in Fig. 2.

The IES makes programming utilization of method for ranking FDV assumed by each user in which the highest rank – 1 is assigned to FDV with the greatest frequency of occurrence, the lowest rank – 7 is assigned to FDV with the least frequency of occurrence while standardized ranks are assigned to FDV having the same frequency of occurrence.

Results of FDV ranking

FDV ranking over the deposit

User	FDV1	FDV2	FDV3	FDV4	FDV5	FDV6	FDV7
1	7	1	2	5	4	3	6
2	5.5	2	1	5.5	3	4	7
3	6.5	2	1	3	4.5	4.5	6.5
4	7	2	3	4	5	1	6
5	6	2	3	4	1	5	7
Sum of ranks	32	9	10	21.5	17.5	17.5	32.5

Coefficient of concordance = 0.774

FDV ranking by horizons

User	FDV1	FDV2	FDV3	FDV4	FDV5	FDV6	FDV7
1	7	1	2	4.5	4.5	3	6
2	6	2	1	4.5	3	4.5	7
3	7	2	1	4	5	3	6
4	6.5	2	3	4	5	1	6.5
5	5.5	1.5	1.5	5.5	4	3	7
Sum of ranks	32	8.5	8.5	22.5	21.5	14.5	32.5

Coefficient of concordance = 0.878

FDV ranking by blocks

User	FDV1	FDV2	FDV3	FDV4	FDV5	FDV6	FDV7
1	7	1	2	4	5.5	3	5.5
2	6	2.5	2.5	5	4	1	7
3	5	3	2	1	6.5	4	6.5
4	7	3	4	5	2	1	6
5	5	3.5	1	3.5	6	2	7
Sum of ranks	30	13	11.5	18.5	24	11	32

Coefficient of concordance = 0.673

FDV ranking by wells

User	FDV1	FDV2	FDV3	FDV4	FDV5	FDV6	FDV7
1	6	1	3	6	2	4	6
2	5.5	1.5	5.5	3	1.5	4	7
3	6	2	4.5	3	1	4.5	7
4	6.5	4	2.5	2.5	6.5	1	5
5	7	2	1	3	5	4	6
Sum of ranks	31	10.5	16.5	17.5	16	17.5	31

Coefficient of concordance = 0.551

Figure 2. Results of ranking and coefficients of concordances.

For each FDV the system computes the sums of ranks over the deposit on the whole, for horizon, blocks and wells.

The concordance of results of experts-users in the IES-CROSS prototype is estimated by this program with the help of concordance coefficients W by Kendal's formula [7].

Through program comparison of computed and tabular χ^2 distribution the statistical significance of concordance coefficients or rankings is estimated with confidence level of 0.95.

The results of implementation of the IES-CPOSS prototype in the laboratory of research were software at the Research and Design Institute of SOCAR have proved serviceability and demonstrated sufficient efficacy of the system.

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