Intelligent control terrosystems under conditions of interval uncertainty

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Abstract
The article is devoted to research and development of a common methodology for the creation of mathematical models and information technologies for solution the problem of decision-making under conditions of uncertainty of input data. The peculiarity lies in the fact that all types of interval uncertainties have a specific semantics and, as a consequence, the "dimension". To solve the problem of decision-making under conditions of "composition" of uncertainties they should be brought to the same "base" form. Research conducted in this work showed that the basic form of representation of interval uncertainty diverse forms in the calculation of utility function of alternatives did not affect the ratio of the alternatives order. These studies are aimed at supporting the decision-making by operators of drilling platforms.
Key words: DECISION-MAKING, UTILITY THEORY, UTILITY FUNCTION, COMPARATOR STRUCTURAL AND PARAMETRIC IDENTIFICATION, IINTERVAL UNCERTAINTY, LIFE CYCLE OF SOLUTION

Introduction

Current state of the marine sector of oil and gas industry is in a period of stagnation stages in comparison with the previous years of development. Active programs of strategic development of the geological industry until 2030 and the Government Program "Development of shipbuilding and technique for the offshore fields working in the 2015-2030 years" try to support the industry, but the global trend of the global crisis does not allow us to perform these perspective directions for full power.

I. Gaida, Managing Director of Boston Consulting Group, says that the process of the continental offshore working is still the most promising direction of the industry development in the near future, especially against the background of the natural deterioration of existing provinces, although against the backdrop of falling of oil and gas prices, many quite promising developments on the offshore have been suspended. The drop in oil prices has been reflected primarily in deepwater and Arctic projects. Offshore oil and gas production around the world lacks of, primarily, investment infusion for geological exploration and high-tech services.

According to the report «The INTSOK Annual Offshore Market Report» of Rystad Energy company, till the end of 2015 the global market for offshore projects will be about $ 241 billion decreased by 13% as compared to 2014. In accordance with the forecast for 2016-2019 years it will continue to fall and reach the bottom of $ 216 billion. In 2017 and in 2018 the trend to growth is projected. The largest offshore oil and gas markets (Australia, the US Gulf, United Kingdom) are subject to recession trend, while the number of medium and small markets (Azerbaijan, Mexico, Indonesia, Ghana) shows the trend to growth. George Economow, Head of Ocean Rig UDW notes that the low level of oil prices has led to a significant drop in demand for drilling rigs. It should be noted that a few years ago the cost of renting the drilling rig (DR) for the offshore reached $ 1 mln/day, but in 2015 these figures decreased critically. Transocean won a contract of Det Norske Oljeselskap to drill four wells in Norway, with an extremely low rent price of DR Transocean Arctic in the $ 180 thous/day.

According to Transocean management, key drilling contractor on work in deep water, the price level providing the efficient development of such projects is $ 70 per barrel. A serious decline in production volumes is probable at the market when saving trends in oil prices in the range of $ 40-50. According to the concepts and applications of the drilling contractor, 2016 will be critical for the stability of market and may lead to another market imbalance in supply and demand for energy resources. Among the leaders in attracting the investments in new developments and projects are offshores of Azerbaijan, Mozambique and Tanzania, projects Eni in Ghana and Shell in Nigeria, the return of offshore projects in Mexico and Iran, as well as the development of prospective structures on the Indonesia offshore.

Market of floating production systems (FPS) continues to be one of the largest. Thanks to improve of technologies the significant growth in the use of popular FPS with underwater pumping was noted at the market of offshore projects since the mid of 90-ies. Since then, production using FPS has increased significantly and amounted to 25% as of the end of 2014. In 2010, the production with their aid has reached the peak of 8.4 MM bbls/d, and, according to forecasts, by 2020 it will be about 9.4 MM bbl/d. Douglas-Westwood notes serious losses of FPS in 2015. The largest investments by volumes are now directed to the creation of floating plants for production of liquefied natural gas (FLNG), which may be the most common solution on the Australian and Asian markets. Today, seven such projects are at the stage of construction and designing. However, so far the world has not commissioned any production based on FLNG. The first such project “Kanovit” should be brought to operation at Petronas on Malaysia offshore in 2016.

SUE “Chernomorneftegaz” announces the opening of a productive gas horizon on the offshore of the Black Sea. The discovery was made in the course of work on the intensification of production on the well No13 Odessa gas field. Significant pressure formation of horizon shows the prospects of gas-saturated sediments of the upper Paleocene and significant increase in production is expected. The recovery from the well has been suspended in order to intake gas from the open deposit. Now the company is preparing to supply additional volumes of gas to the shore in Crimea gas transportation system. In prospect the development of the Gordievich oil and gas area in the Black Sea is expected. According to various estimates, between 68 and 100 billion cubic meters of gas are storaged there.

It is estimated that up to 30% of the undiscovered natural gas reserves and 10% of undiscovered oil reserves are located in the Arctic.

The fundamental estimation of stocks volumes of Arctic hydrocarbon does not exist: the United Nations gives a figure of 100 billion tons of oil and 50 trillion cubic meters of gas. Geological Services of USA and Denmark estimate oil reserves in the Arctic as 83 billion tones or 13% of the world’s undiscovered deposits. A significant portion of oil reserves lies near Alaska, and the main gas-bearing fields are located at the coast of the Russian Federation.

It should be noted that the process of offshore drilling is the most complex in the development of hydrocarbon deposits (at depths of more than a kilo- meter). The drilling technologies of high reliability and maintainability are necessary, which are now lacking entirely in the industry and it leads to increased need in large investments in the development of offshore production technologies and attracting of new technologies.

The study of Russian industry market conditions shows that to ensure manufacture of equipment for the development of offshore fields is not possible in its entirety (up to 90% of the equipment is supplied by imports and the imposed sanctions have also substantial negative impact).

There is no doubt in the fact that the reliable data obtaining for decision-making by the operator of marine intelligent control terrosystems (MICT) in conditions of uncertainty and risk of the environment requires sufficient completeness of the analysis methods and models of inaccuracies and uncertainties of data in MICT. In this connection it is necessary to analyze the models and methods of inaccuracies and uncertainty of MITC data. Traditionally two means of providing incomplete data are used: the theory of probability and the theory of errors. However, these theories have a number of limitations and in the probabilistic model the limiting case of a complete fuzzy knowledge is taken into account badly, because the set of mutually independent events is always assumed as given, the equal probabilities (in the finite case) are attributed to which by virtue of the maximum entropy principle [1].

The analysis of literature data and formulation of the problem

Resulting indicators calculated by simulation models, that connect input data to output variables in this case will also have some uncertainty. Uncertainty of input data and simulation results requires that, for the purposes of constructive analysis, they should be presented as some related areas on the scales characterizing the possible valid values for each indicator.

Further we assume that any of the parameters containing uncertainty can be represented as an interval (interval number) [D_l , D_r], given by left D_l and right D_r point values on the measuring scale. With this definition, the uncertainties will differ only in the fullness, type and presentation of a priori information about the distribution character of possible values within the interval. According to this feature we can distinguish three main types of uncertainty [2, 3]: statistical (probabilistic), fuzzy, interval (equally probable).

A fuzzy set is described by a carrier of a fuzzy set, which represents the range of possible values of the linguistic variable and a pair $\langle h,\mu(h)\rangle$, where h – point value of the fuzzy set element, and $\mu(h)$ point value of the membership function of the fuzzy set, which qualitatively characterizes truth degree of a particular predication of «h approximately equals H» type.

The set of values h, on which $\mu(h)\neq 0$, determines the range of possible values of the fuzzy variable, i. e. carrier of the fuzzy set. When the form of membership function $\mu(h)$ and of the fuzzy set carrier (interval boundary of the possible values) are heuristically set by one or a group of experts and reflects according to their individual or collective agreed subjective opinion respectively.

Interval (equally probable) uncertainty [4] in its original form is the least informative, as it only defines the boundaries of the possible values, but does not contain any information on the distribution or preference values within the interval. On the basis of subjective heuristic considerations, it can be transformed by experts in the subjective probability, uncertainty or the fuzzy set.

In the particular case the left and right interval boundaries of uncertainty may coincide, and then the uncertainty becomes the point determined objective value.

In other cases, the value of uncertainty interval is relatively small, and considering functional features of the system can be neglected, taking as a point of the determined value of the left (right) boundaries of the interval or average. This procedure will be called subjective determinization.

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The objective of this study is to improve the quality of intellectualization of information processing through the creation of decision support systems (DSS) considering the normative universal methodology, mathematical models, criteria and tools in conditions of uncertainty of the outside marine environment applicable to offshore platforms and rigs. Formulation and formalization of objective is a conceptual and also difficult stage. This is due to the fact that the formulation of the objective has an axiomatic nature and largely determines the characteristics of the system. That is why foreign and domestic standards governing the design process determine the objective-setting process as a special pre project phase. It consists of two procedures: a technical and economic feasibility (TEF), during which evaluation of the fundamental feasibility and advisability of objective achievement is carried out; technical requirements specification (TRS) is drawn up, which is on the quantitative and qualitative levels defines all relevant characteristics (properties) of the system.

The importance, complexity and significance of the stage of objective formation and formalization are characterized by the fact that up to 40% of total amount of time and financial resources are spent on it [5]. Further, we will assume the objective-setting stage as external to the decision-making procedure and the emerging uncertainties will not be taken into account.

Materials and methods of research

The formulate models of scalar multifactorial estimation, methods of regularization of ill-posed problems, the theory of interval analysis to account for the uncertainties of the original data, machinery of probability theory, fuzzy sets, equally probable intervals to account for uncertainties, expert evaluation method to determine the order relation on the initial set of alternatives, methods of comparator identification and genetic algorithms to solve the problems of structural-parametric identification of evaluation model were used in the work for solving the problems of utility theory.

Currently, there is no universal, invariant kind of uncertainty and measurement metric is “uncertainty”, so when making decisions specialized task-oriented metrics are applied. This circumstance determined the separation of decision-making problems in conditions of uncertainty into three main classes.

Research results

Let us consider the set events associated with the base of inaccurate and uncertain knowledge understood as subsets of the universal set Ω called certain event. The empty set $\varnothing$ is identified with the impossible event. It is assumed that to the each event $A \subset \Omega$ real number g(A) can be put in correspondence, which is given by the subject - "keeper" of the knowledge base (or obtained by the procedure of processing of the information stored in the information system memory). Value $g(A)$ evaluates degree of certainty available to the subject in relation to the event A considering current level of awareness. By definition, the value $g(A)$ grows with certainty increasing. Furthermore, if A is the certain event, it is assumed that $g(A) = 1$, and if A is an impossible event, then it is believed that $g(A) = 0$.

Hence, the measure is determined by the function:

$$g : P(\Omega) \to [0,\ 1],$$

where $P(\Omega)$ - cardinality of a set Ω.

In order to consider the function as a fuzzy measure, it should have the following properties of fuzzy measures:

1) $g(\varnothing) = 0;\ g(\Omega) = 1;$ - limitedness (1)

2) if $A_1 \subseteq A_2$, than $g(A_1) \le g(A_2)$; - monotoneness (2)

3) if $A_1 \subseteq A_2 \subseteq \cdots$ or $A_1 \supseteq A_2 \supseteq \cdots$, than $\lim\limits_{i\to\infty} g(A_i) = g \lim\limits_{i\to\infty}(A_i)$ – continuity (3)

The requirement (1) (limitedness) is obvious. The requirement (2) (monotoneness) does not allow a subset of the other subset Ω have more than including subset. According to the requirement (3) (continuity), the measures limit of infinite monotonous sequence of subsets Ω should coincide with the limit measure of this sequence. To the discrete systems, in which Ω is always a finite set, the continuity requirement, of course, does not apply.

These set functions g were proposed by Sugeno for estimating the uncertainty called fuzzy measures. Dubois and Prades used the name "uncertainty measure".

Inequalities (2) and (3) follow directly from the monotony axioms (1) and characterize the sum $A \cup B$ or intersection $A \cap B$ of events:

$$\forall A,\ B \subseteq \Omega,\ g(A \cup B) \ge \max(g(A),\ g(B)), \quad (4)$$

$$g(A \cap B) \le \min(g(A),\ g(B)). \quad (5)$$

The limiting case of uncertainty measures is functions of set L such that

$$\forall A,\ B,\ \mathrm{L}(A \cup B) = \max(\mathrm{L}(A),\ \mathrm{L}(B)). \quad (6)$$

They are called measures of possibility by Zadeh.

The measures of possibility satisfy the relation:

$$\max(\mathrm{L}(A),\ \mathrm{L}(\overline{A})) = 1. \quad (7)$$

This is interpreted as a fact that from two opposing events, one is possible.

If the set is Ω, then every L measure of possibility can be identified by its values on the one-point subsets of L:

$$\mathrm{L}(A) = \sup\{\pi(\omega) \mid \omega \in A\}, \quad (8)$$

where $\pi(\omega) = \mathrm{L}(\{\omega\})$; π - is a mapping from Ω to [0, 1], called possibility distribution function.

When reaching the equality in formula (3) the other limiting case of uncertainty measures can be presented, wherein the set class of functions is defined called measures of necessity (N), which satisfies the axiom (6):

$$\forall A,\ B,\ N(A \cap B) \ge \min(N(A),\ N(B)). \quad (9)$$

The necessity distribution function can be based on the possibility distribution function:

$$N(A) = \inf\{1 - \pi(\omega) \mid \omega \notin A\}. \quad (10)$$

Measures of necessity satisfy the ratio:

$$\min(N(A),\ \mathrm{N}(\overline{A})) = 0, \quad (11)$$

which eliminates the simultaneous necessity for two opposite events.

If there is an information about the occurrence of events in the form of measured frequencies elementary events obtained measure of uncertainty naturally satisfies the axiom of additivity

$$\forall A,\ B,\ A \cap B = \varnothing,\ P(A \cup B) = P(A) + P(B), \quad (12)$$

is identified as probability measure that is monotonous for the condition (2). Formula (12) is a probability equivalent of axioms (6) and (9).

Discussion of the results

The analysis of methods and models of data inaccuracies and uncertainties in MICT allowed us to formulate the control problem of databases fuzzy models of knowledge in MICT for offshore drilling platforms. Solution of the problem of bases of fuzzy models of knowledge control in MICT requires study of the following questions: the basic concepts of the theory of fuzzy sets and fuzzy logic for the tasks of BFK forming; necessary and sufficient conditions of BFK control in MICT; interaction models of MICT and operator using the methods of fuzzy logic. Let us consider the sources and types of uncertainties when solving MICT problems. We consider sources and types of fuzzy uncertainty in the solution of MICT problems.

As follows from the definition of an abstract system all the properties (characteristics) of the system are generated by its structure (2). This implies that for the synthesis of the system with specified technical requirements specification and certain properties P_c, it is necessary to define such subset of elements $P_c \to M : M_c$ and ratios $R_c \to R : R_c$, on which in principle the structures that generate required properties can be synthesized:

$$P_c = \theta(C) = \theta\langle M_c \times R_c \rangle. \quad (13)$$

Where M and R – corresponding universums, which means that for a conscious purposeful synthesis of the system the abstract model is required that establishes a formal link between the structure of the system C and its properties P.

For the formal definition of the abstract model we use the concept of an abstract formal language, which is understood as some alphabet (set of concepts, symbols, and operands) and grammar that defines the rules for recording of statements in that language. Then any expression, written on the abstract language is a formula, a set of formulas describing the process, phenomenon or whole system is the abstract model. Traditionally in cybernetics system is considered as a "black box", which input, in the general case, receives multidimensional lead-in (independent, control) action $Z = \langle Z_l \rangle,\ \ l = \overline{1,L}$. The multidimensional variable is observed on the output of the system $Y = \langle y_h \rangle,\ h = \overline{1,H}$, reflecting the system response. Connection between the input and output is described by model

$$Y = F(Z), \quad (14)$$

where F – operator establishing the connection between Y and Z. In this formulation the output variables componentwise or groups determine the properties of the system C, and lead-in action Z defines specific quantitative values of the elements and structure relations, i. e. sets some particular possible variant of the structure $x \in X^P$. The principal feature of abstract simulation models is inaccurate of the real world description. This means that there is always a simulation error

$$\Delta Y = |Y_M - Y_E| \neq 0,$$

where Y_M, Y_E – values calculated respectively according to the model and actual measured experimentally. Depending on the specific conditions error (19) may be greater or lesser but always different from zero.

From a formal point of view the definition of the set X^P means mapping of required system target properties P on the elements universums M and relations R with the subsequent formation of all possible structures on selected subsets. However, this problem is unrealizable, especially due to the universums of elements and relations are not defined. In practice, to form X^P the expert solutions [11]; information about known models [9, 10]; CBR, etc. [7,8] are used.

We assume that the set of states of the environment S is given clearly and stochastic uncertainty manifests itself in a random implementation of states $s \in S$ that do not depend on the choice of alternative $x \in X$. Stochastic uncertainty is described by density of probability distribution $p(s)$. For illustrative purposes, but without loss of generality, further we assume that the X and S sets are counting, i. e. $X\{x_i\},\ i = \overline{1,n}$; $S = \{s_j\},\ j = \overline{1,m}$. Then, when selecting a particular decision $x_i \in X$ and random implementation of one of the possible states of the environment $s_j \in S$, the solving effectiveness $E(x,s)$ is characterized by two partial criteria: assessment of the expected effect $f(x_i, s_j)$ and the possibility of its implementation $p(s_j)$, i.e.

$$E(x_i) = \mathrm{F}[f(x_i, s_j), p(s_j)].$$

In general, summing up conducted researches we can draw the following **conclusions**:

1. The formalization problem of decision-making procedures in the conditions of the initial information interval uncertainty of marine environment for drilling rigs is very relevant, since it is a prerequisite for its automation, which in turn determines the prospects of creating, development and improvement of drilling platforms of offshore intelligent information systems.

2. The difficulty of solving this problem is determined by the fact that the decision-making procedure is an intellectual process, which mathematical model identification requires the development of special techniques different from the natural processes identification methods. This is due to the carrier of initial information is not "nature", but the men and so special methods for obtaining this information are required.

3. The main methods of obtaining information about the intellectual procedures are introspective methods, in particular methods of expert evaluation and comparator identification, which are just starting to be used for DR.

4. Regardless the synthesis methods of the multi-factorial assessment model includes the uncertainty due to the subjectivism of initial information sources. Currently this uncertainty in most cases is not taken into account in the intellectual support systems of decision-making for drilling platforms operators.

5. A general approach to solving problems of multi-criteria optimization taking into account the uncertainties of the marine environment consists in decomposition of the original problem into a sequence of two conditionally independent tasks: formation of scalar deterministic multi-factoral assessment; decision-making under conditions of uncertainty of the environment.

6. Methods of decision-making under uncertainty

condition are highly specialized and oriented on certain types of uncertainties: stochastic, fuzzy or interval. Correct methods of their mutual transformation or taking into account their different compositions are underdeveloped.

7. In all these areas intensive studies are carried out, but in general, currently the problem of multi-criteria decision-making under uncertainty conditions is far from comprehensive solution for intelligent technologies of drilling platforms.

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