The article reveals that creating mobile applications separately for Android and iOS is becoming a complex and costly process. There is a need for a common solution that will simplify the process of development, support, testing and deployment on various platforms. This solution should standardize the process of creating mobile applications.

React Native, created by Facebook, represents a significant milestone in the development of cross-platform mobile application development. Thanks to an active and powerful community, React Native has become the most popular tool for creating cross-platform applications. However, Google decided to develop its own solution, Flutter, after carefully analyzing the advantages and disadvantages of React Native. Flutter is focused on optimizing for mobile devices and strives to provide developers with a complete and definitive solution for creating cross-platform applications.

This article analyzes the key characteristics of React Native and Flutter, researching and comparing these characteristics in order to identify the reasons for their differences. The authors of the article hope that the results of the study will help improve cross-platform development and ensure further progress in this area.

Key words: *Andorid, movies, development, artificial intelligence, Architecture, cross-platform, research, integration, IOS, React Native, Flutter.*

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FUZZY DECISION-MAKING PROBLEMS FOR CONTROLLING OPERATING MODES OF TECHNOLOGICAL SYSTEMS AND METHODS FOR SOLVING THEM

Abstract: *Statements of decision-making problems for the control of fuzzy technological objects are formalized and obtained, and methods for solving them are proposed. The object of study is the heating stations of the «hot» main oil pipeline. Since such objects are often characterized by multicriteria and often operate in conditions of unclear initial information, the tasks are formalized in the form of multicriteria decision-making problems in a fuzzy environment. Based on the modification of various optimality principles, new mathematical formulations of the problems to be solved were obtained and interactive heuristic algorithms for solving them were developed. The novelty of the proposed approaches to solving formalized fuzzy problems* *from well-known methods for solving fuzzy problems lies in the fact that problems are posed and solved without first converting them to equivalent deterministic options, which does not reduce the loss of original fuzzy information and makes it possible to obtain more adequate and effective solutions. An example is given of the practical application of the proposed approach to solving decision-making problems by implementing one of the developed algorithms when solving the problem of choosing an effective operating mode for the oil heating station of the Uzen-Samara oil pipeline at the Atyrau point.*

Key words: *fuzzy decision-making, multicriteria optimization, information, membership function, principles of optimality, decision maker (DM).*

Introduction

In practice, decision-making problems often arise when managing the operating modes of technological objects, which are characterized by multicriteria and fuzziness of the initial information. The complexity, large number of parameters and multicriteria of such technological objects and the fuzziness of the initial information complicate the formalization, mathematical formulation and solution of such problems [1-3].

Recently, in the scientific literature and publications, problems and approaches to solving multicriteria decision-making problems have been actively discussed [4, 5], including in conditions of fuzzy initial information [6-8]. Methods for solving these problems in a fuzzy environment are based on the use of methods from fuzzy set theories [1, 2, 5, 9, 10]. The problems of setting and solving multicriteria problems of choosing optimal parameters and operating modes of technological units are considered in works [3, 5, 7, 11].

The decision-making problems studied and solved in this work on the optimal control of the operating modes of technological units of the main oil pipeline are related to important scientific and practical issues of decision theory, the theory of fuzzy sets and multicriteria optimization, which is a very relevant problem in the oil pumping industry. The purpose of this work is to study and solve issues of formalization and formulation of decision-making problems to control the operating modes of oil pipeline technological units in a fuzzy environment, as well as the development of algorithms for solving them. When formulating and solving a problem, the ideas of compromise decision-making schemes are used, modified and adapted to the conditions of fuzziness of the initial information [5, 11, 12]. Since many technological objects are often characterized by multicriteria and fuzziness of the initial information and control criteria, the studied and solved problems are an urgent task of theory and practice.

Problem statement

The decision-making problem in the general case can be formalized in the following form: <Decision-making problem> = {V, V_S, V_P are given, W is required to be provided}, where V – given conditions; V_S – set of possible states (modes of operation) of an object; V_P – a set of possible operators that ensure the transition of an object from one state to another; W – desired operating mode of the object. In this case, the solution to the decision-making problem consists in choosing a sequence of operators to transfer an object from the state at the current moment to the desired state. Thus, decision making is a process that consists of evaluating possible solutions (alternatives) and, taking into account given conditions, selecting the best solution according to given criteria.

Under the conditions of multicriteria and fuzziness of initial information, the task of managing the operating modes of technological objects can be formalized as a multicriteria decision-making problem in a fuzzy environment. The task of decision-making is to evaluate possible solutions, which allows to choose the best of them according to given economic and environmental criteria [12].

Let $f(x) = f_1(x),...,f_m(x)$ is a vector of criteria that evaluates the quality of the oil pipeline technological complex. For example, $f_1(x), f_2(x),...,f_k(x)$ – respectively, pumping volume, profit, etc.; $f_{k+1}(x), f_{k+2}(x),...,f_m(x)$ – local criteria for assessing environmental safety, for example, the cost of environmental protection measures, damage from environmental pollution with oil, oil products and transportation waste, etc.. Each of the m criteria depends on the vector of n parameters (control actions, regime parameters) $x = (x_1,...,x_n)$, for example: temperature and pressure; rheological properties of raw materials, reagent consumption, etc. In practice, there are always various restrictions (economic, technological, financial, environmental), which can be described by some functions – constraints $\varphi_q \geq b_q$, $q = \overline{1, L}$. Operating parameters also have their own change intervals, specified by the technological regulations of the unit and the requirements of environmental protection measures: $x_i \in \Omega = [x_i^{\min}, x_i^{\max}]$, where $x_i^{\min}$ – lower, $x_i^{\max}$ – upper change limits of the parameter x_i. Constraints may be fuzzy: $\tilde{>}$ – more than or approximately equal, $\tilde{<}$ – less than or approximately equal, $\cong$ – approximately equal

It is required to make decisions on the selection of the most effective (optimal) solution - the optimal operating mode of the technological complex of the main oil pipeline, ensuring the extreme value of the vector of criteria when fulfilling the specified constraints and taking into account the preferences of the decision maker (DM). In our cases, decision makers are operators for managing oil pumping modes through pipelines; they control and select the operating mode of an oil pipeline technological object, for example, oil heating stations, oil pumping stations, providing optimal values of local control criteria: pumping volume, safety and reliability of the mode, etc.

Results

Let us formulate a mathematical formulation of the formalized decision-making problem to control the operating modes of technological objects in conditions of multicriteria and fuzziness of the initial information.

Let there be a normalized vector of criteria of the form - $\mu_0(x) = (\mu_0^1, ..., \mu_0^m)$) and L constraints with fuzzy instructions – $\varphi_q(x) \tilde{>} b_q$, $q = \overline{1, L}$. Let us assume that the constraint fulfillment membership functions $\mu_q(x)$, $q = \overline{1, L}$ for each constraint are constructed as a result of expert procedures and dialogue with specialist experts. Let the weight vector, which reflects the mutual importance of the criteria ($\gamma = (\gamma_1, ..., \gamma_m)$) and constraints ($\beta = (\beta_1, ..., \beta_L)$) at the time of setting the problem, be known [13, 14].

Then the problem of choosing optimal operating modes of technological objects according to economic and environmental criteria can be written as the following decision-making problem in a fuzzy environment:

$$\max_{x \in X} \mu_0^i(x), \; i = \overline{1, m}$$
$$X = \left\{ x : \arg \max_{x \in \Omega} \mu_q(x), \; q = \overline{1, L} \right\}.$$

Based on the idea of the *main criterion method and the Pareto principle of optimality*, the given decision-making problem with a vector of criteria and constraints [15, 16] can be written in the following formulation:

$$\max_{x \in X} \mu_0^1(x), \tag{1}$$

$$X = \left\{ x : x \in \Omega \wedge \arg\left(\mu_0^i(x) \geq \mu_r^i\right) \wedge \arg \max_{x \in \Omega} \sum_{q=1}^{L} \beta_q \mu_q(x) \wedge \sum_{q=1}^{L} \beta_q = 1 \wedge \beta_q \geq 0, i = \overline{2, m}, \; q = \overline{1, L} \right\} \tag{2}$$

where $\wedge$ – logical sign “and”, requiring that all statements associated with it be true, μ_r^i – boundary values for local criteria $\mu_0^i(x), i = \overline{2, m}$, specified by the decision maker.

According to the main criterion method, the main (in terms of importance) criterion is optimized, and the remaining local criteria are included in the constraints. According to the Pareto principle of optimality, the decision maker selects the optimal solution from an effective set, in which the improvement of one of them leads to the deterioration of the other.

By changing μ_r^i and the constraint importance vector $\beta = (\beta_1, ..., \beta_L)$, we can obtain a family of solutions to the problem (1)–(2): $x^*(\mu_r, \beta)$. The choice of the best solution is carried out on the basis of dialogue and taking into account the preferences of the decision maker. To solve the multicriteria decision-making problem of determining the desired operating mode of oil pipeline units in formulation (1)-(2), this paper proposes the following heuristic algorithm based on a modification of the principles of the main criterion and Pareto optimality for working in a fuzzy environment and their combination.

***GK-PO algorithm*:**

1. $p_q, q=\overline{1,L}$ - the number of steps for each q-th coordinate and a number of priorities for local criteria $I_k=\{1,...,m\}$ (the main criterion must have priority 1) is specified and and the value of the constraint weight vector is entered $\beta=(\beta_1,...,\beta_L)$, taking into account the importance of local constraints.
2. The decision maker assigns boundary values (constraints) of local criteria $\mu_r^i(x), i=\overline{2,m}$.
3. $h_q=1/p_q, q=\overline{1,L}$ - step sizes for changing the coordinates of the weight vector β are determined.
4. A set of weight vectors $\beta^1,\beta^2,...,\beta^N$, $N=(p_1+1)(p_2+1)...(p_L+1),$ is determined by varying the coordinates on the segments [0,1] with a step h_q
5. The term-set $T(X,Y)$ is determined and the membership functions for fulfilling the constraints $\mu_q(x)$, $q=\overline{1,L}$ are constructed.
6. The main criterion (1) is maximized on the set X determined by (2), the current solution is determined: $x(\mu_r^i,\beta),\ \mu_0^1(x(\mu_r^i,\beta)),...,\mu_0^m(x(\mu_r^i,\beta));\ \ \mu_1(x(\mu_r^i,\beta)),...,\ \ \mu_L(x(\mu_r^i,\beta)),$ $i=\overline{2,m}$.
7. The decision is presented to the decision maker. If the current results do not satisfy the decision maker, then new values of $\mu_r^i(x), i=\overline{2,m}$ are assigned to them and (or) the values of β are adjusted, and a return to point 3 is made. Otherwise, go to point 8.
8. The search for a solution stops, the results of the final choice of the decision maker are displayed: values of the control vector $x^*(\mu_r^i,\beta)$; values of local criteria $\mu_0^1(x^*(\mu_r^i,\beta)),...,$ $\mu_0^m(x^*(\mu_r^i,\beta))$ and degree of fulfilling the constraints $\mu_1(x^*(\mu_r^i,\beta)),...,\mu_L(x^*(\mu_r^i,\beta))$.

By modifying various compromise decision-making schemes for the case of fuzziness, we can obtain other statements of multicriteria decision-making problems in a fuzzy environment and propose algorithms for their solution.

Using the ideas of the methods of the *main criterion and the ideal point* and modifying them for the case of fuzziness, the multicriteria decision-making problem with the fuzziness of the initial information can be put in the following form:

$$\max_{x\in X}\mu_0^1(x), \tag{3}$$

$$X=\left\{x: x\in\Omega\wedge\arg\left(\max_{x\in\Omega}\max\mu_0^i(x)\geq\mu_r^i\right)\wedge\arg\mu_q(x)\geq\min\left\|\mu(x)-\mu^u\right\|_D), i=\overline{2,m}, q=\overline{1,L}\right\} \tag{4}$$

where $\left\|\mu(x)-\mu^u\right\|_D$ - used metric D, components $\mu(x)$ and coordinates of the ideal point μ^u are defined as follows $\mu(x)=(\mu_1(x),...,\mu_L(x))$, $\mu^u=(\max\mu_1(x),...,\max\mu_1(x)$. It is possible to use μ^u units as the coordinates of the ideal point: $\mu^u=(1,...,1)$.

The essence of the main criterion method is disclosed above. The ideal point method allows you to find the optimal solution based on minimizing the measure (distance) of the current solution from the ideal solution (point).

To solve the multicriteria decision-making problem (3)–(4), this paper proposes a method developed on the basis of modification of compromise schemes of the *main criterion and ideal point* methods.

Based on the application of the idea of the main criterion method to a vector of local criteria, and the idea of an ideal point to constraints, modifying them for the case of fuzziness, we propose the following algorithm for solving the multicriteria decision-making problem (3)–(4) with fuzziness of the initial information:

***GK-IT algorithm*:**

1. A number of priorities are set for local criteria $I_k = \{1,...,m\}$ (the main criterion must have priority 1).
2. Based on information received from decision makers and specialist experts, the term set of fuzzy parameters $T(X,Y)$ is determined and for each constraint membership functions for fulfilling constraints $\mu_q(x)$, $q = \overline{1,L}$ are constructed.
3. The decision maker assigns boundary values of local criteria $\mu_r^i(x), i = \overline{2,m}$.
4. The coordinates of the ideal point are determined. As the coordinates of these points, you can use the maximum values of the membership function $\mu^u = (\max \mu_1(x),..., \max \mu_L(x))$ or unit $\mu^u = (1,...,1)$ (if the membership functions are normal).
5. The type of metric $\|\mu(x) - \mu^u\|_D$ is selected, which determines the distance of the current solution x^* from the ideal point – μ^u.
6. Problem (3)–(4) is solved and the current solution is determined: $x(\mu_r^i, \|\mu(x) - \mu^u\|_D)$– control parameter vector value, $\mu_0^1(x(\mu_r^i, \|\mu(x) - \mu^u\|_D))$, $\mu_0^2(x(\mu_r^i, \|\mu(x) - \mu^u\|_D))$, ..., $\mu_0^m(x(\mu_r^i, \|\mu(x) - \mu^u\|_D))$ – local criteria values and $\mu_1(x(\mu_r^i, \|\mu(x) - \mu^u\|_D))$, $\mu_2(x(\mu_r^i, \|\mu(x) - \mu^u\|_D))$, ..., $\mu_L(x(\mu_r^i, \|\mu(x) - \mu^u\|_D))$, $i = \overline{2,m}$ - membership function values for fulfilling the constraints.
7. The decision maker is presented with the received current solution. If the current results do not satisfy the decision maker, then new values are assigned to them, and (or) a new type of metric $\|\mu(x) - \mu^u\|_D$ is selected and the search for an acceptable solution is repeated, i.e., a return to the previous step is made, otherwise a transition is made to the next step 8.
8. The final solution is derived that satisfies the decision maker: values of control and operating parameters $x^*(\mu_r^i, \|\mu(x) - \mu^u\|_D)$, that provide optimal values of local criteria $\mu_0^1(x^*(\mu_r^i, \|\mu(x) - \mu^u\|_D))$, $\mu_0^2(x^*(\mu_r^i, \|\mu(x) - \mu^u\|_D))$, ..., $\mu_0^m(x^*(\mu_r^i, \|\mu(x) - \mu^u\|_D))$ and maximum values of the membership functions for fulfilling the constraints $\mu_1(x^*(\mu_r^i, \|\mu(x) - \mu^u\|_D))$, $\mu_2(x^*(\mu_r^i, \|\mu(x) - \mu^u\|_D))$, ..., $\mu_L(x^*(\mu_r^i, \|\mu(x) - \mu^u\|_D))$.

The given formulations of new multicriteria selection problems and the developed algorithms for solving them are based on the use of modified deterministic methods of multicriteria optimization and compromise decision-making schemes. The results obtained are a generalization and development of these methods in the case of fuzziness of the initial information.

Practical application, comparison and discussion of results

As an example of the implementation of the proposed approach to the optimization of technological objects, let us consider the formalization of the formulation and solution of the problem of adopting an effective operating mode of the oil heating station (OHS) of the Uzen-Samara oil pipeline at the Atyrau point. The main task of the OHS is to ensure trouble-free and uninterrupted operation of heating furnaces and structures attached to them, ensuring optimal technological operating conditions for the «hot» oil pipeline. At the same time, the following types of decision-making problems for optimizing criteria are solved: minimizing the cost of heating and pumping oil; minimizing fuel and operating costs; increasing the degree of reliability of mechanisms and devices; increasing the environmental safety of the oil pipeline.

The volume of pumped oil can be determined by the indicators of various devices (flow meters, etc.). In our case, the volume of pumped oil is measured in units of thour. As for assessing quality and environmental safety, the situation here is much more complicated. It is very difficult and not always possible to evaluate the quality of work of the technological and production complex of an oil pipeline, and the environmental safety of the object's operation in one number. Often these indicators are difficult to measure quantitatively and are characterized by uncertainty and fuzziness of the initial information. In fact, quality indicators and environmental safety indicators are often characterized by restrictions such as «no more» and «about», i.e. are fuzzy.

In practice, we want economic criteria (productivity, profit, pumping volume, etc.) and quality indicators to be maximum, and environmental impact on the environment to be minimal. But, as you know, these criteria are often contradictory and it is often not possible to improve them at the same time. The task is to find the optimal solution in the field of compromises, depending on the production situation and plan, and also satisfying the decision maker.

Thus, using the above problem statements, the decision-making problem in controlling the modes of the oil transportation process through the main oil pipeline is set as follows:

Let $f(x) = F(f(x)) = \mu_0^i(x), i = \overline{1,3}$ – are normalized local criteria assessing the volume of oil pumping ($\mu_0^1(x)$), temperature ($\mu_0^2(x)$) and pressure ($\mu_0^3(x)$)at the outlet of the OHS. Let us assume that for each fuzzy constraint describing environmental indicators $\varphi_q(x) \tilde{\geq} b_q, q = 1,2$, the membership functions of its implementation $\mu_q(x)$, $q = 1,2$ are constructed. Let us know or define a number of priorities for local criteria $I_k = \{1, 2, 3\}$ and a weight vector reflecting the mutual importance of these constraints $\beta = (\beta_1, \beta_2)$.

The criterion and constraints depend on the vector of parameters $x_i, i = \overline{1,4}$ (x_1 (x_1, x_2, x_3, x_4 – temperature, x_2 – pressure, x_3 – fuel consumption, x_4 – oil consumption at the furnace inlet). These dependencies are determined on the basis of mathematical models developed in [17, 18,19].

A formalized task, in the conditions of fuzziness of some part of the initial information, can be written similarly to (3)–(4) in the form of the following multicriteria decision-making problem in a fuzzy environment:

$$\max_{x \in X} \mu_0^1(x), \tag{5}$$

$$X = \left\{x : x \in \Omega \wedge (f_i(x) \geq b_i) \wedge \arg\left(\mu_q(x) \geq \min_{x \in \Omega} \left\|\mu(x) - \mu^u\right\|_D\right) i = 2,3, q = 1,2\right\} \tag{6}$$

where $f_i(x), i = 2,3$ – constraint functions for temperature and pressure at the outlet of oil heating stations, $\left\|\mu(x) - \mu^u\right\|_D$ – used metric *D*, $\mu(x) = (\mu_1(x), \mu_2(x))$, $\mu^u = (\max \mu_1(x), \max \mu_2(x))$ or $\mu^u = (1,.1)$.

The solution to this problem is the value of the vector of optimized regime parameters $x^* = (x_1^*, x_2^*, x_3^*, x_4^*)$, which provides the extreme value of the criterion when the specified constraints are met, taking into account the preferences of the decision maker and satisfying it.

To solve the problem (5)-(6), we use a modification of the GK-IT algorithm.

1. A number of priorities are set for local criteria $I_k = \{1, 2, 3\}$ (the main criterion is the volume of oil pumped through the pipeline, which has priority 1, priority 2 is assigned to the temperature at the furnace outlet, pressure at the furnace outlet has priority 3).

2. Based on information received from decision makers and expert specialists, a term set of fuzzy parameters is determined and for each constraint, membership functions for fulfilling the constraints $\mu_q(x)$, $q = 1,2$ are constructed.

Based on the results of expert assessments and studies, the following membership functions for fulfilling the constraints are constructed:

$\mu_1(x) = \exp(0.20 | a_1 - 50.0 | \cdot 0.5)$; $\mu_2(x) = \exp(0.10 | a_2 - 80.0 | \cdot 0.7)$;

where a_1, a_2 – average numerical values of fuzzy parameters, respectively: temperature and pressure of the furnace (oil heating station) at the outlet.

3. The type of the constraint function $f_i(x), i = 2,3$ is determined and the value of $b_i, i = 2,3$ is set. Based on the results of the research, it is determined:

$f_1(x) = 7 + 1,2 \cdot x_1 - 0.25 \cdot x_2 + 5.7 \cdot x_3 - 1.3 \cdot x_4 + 1.8 \cdot x_1^2 + 8.3 \cdot x_3^2; b_1 = 55$,

$f_2(x) = 0.25 - 1.31 \cdot x_1 + 7.35 \cdot x_2 - 3.1 \cdot x_3 + 2.25 \cdot x_4 + 9.85 \cdot x_2^2 + 8.7 \cdot x_3^2; b_2 = 8.5$

4. The coordinates of the ideal point are determined. As the coordinates of these points, you can use the maximum values of the membership function. In our case, the membership functions are normal, then $\mu^u = (1,1)$.

5. The type of metric $\left\| \mu(x) - \mu^u \right\|_D$ is selected, which determines the distance of the current solution ($\mu(x)$) from the ideal point (μ^u). In our case, the type of metric is defined as follows:

$$\left\| \mu(x) - \mu^u \right\|_E^2 = \sum_{q=1}^{2} (\beta_q (\max_{x \in \Omega} \mu_q(x) - \mu_q(x)))^2 ,$$

where β_q - weight coefficient of the q-th fuzzy constraint.

6. Problem (5)–(6) is solved (in our case, mathematical programming methods are used) and the current solution is determined:

1) $x(b_i, \sum_{q=1}^{2} (\beta_q (\max_{x \in \Omega} \mu_q(x) - \mu_q(x)))^2)$, $i = 2,3$ – control parameter vector value;

2) $\mu_0^1(x(b_i, \sum_{q=1}^{2} (\beta_q (\max_{x \in \Omega} \mu_q(x) - \mu_q(x)))^2))$, $\mu_0^2(x(b_i, \sum_{q=1}^{2} (\beta_q (\max_{x \in \Omega} \mu_q(x) - \mu_q(x)))^2))$, $\mu_0^3(x(b_i, \sum_{q=1}^{2} (\beta_q (\max_{x \in \Omega} \mu_q(x) - \mu_q(x)))^2))$, $i = 2,3$ – local criteria values;

3) $\mu_1(x(b_i, \sum_{q=1}^{2} (\beta_q (\max_{x \in \Omega} \mu_q(x) - \mu_q(x)))^2))$, $\mu_2(x(b_i, \sum_{q=1}^{2} (\beta_q (\max_{x \in \Omega} \mu_q(x) - \mu_q(x)))^2))$, $i = 2,3$– membership function values for fulfilling the constraints.

7. The decision maker is presented with the received current solution. If the current results do not satisfy the decision maker, then new boundary values $\mu_r^1(x)$, $\mu_r^2(x)$ are assigned to them, and (or) a new type of metric $\left\| \mu(x) - \mu^u \right\|_D$ is selected and the search for an acceptable solution is repeated, i.e. a return to the previous step is carried out, otherwise a transition is made to the next step 8.

8. The final solution is derived that satisfies the decision maker: values of control and operating parameters $x^*(b_i, \sum_{q=1}^{2} (\beta_q (\max_{x \in \Omega} \mu_q(x) - \mu_q(x)))^2)$ that provide optimal values of local criteria $\mu_0^1(x^*(b_i, \sum_{q=1}^{2} (\beta_q (\max_{x \in \Omega} \mu_q(x) - \mu_q(x)))^2))$, $\mu_0^2(x^*(b_i, \sum_{q=1}^{2} (\beta_q (\max_{x \in \Omega} \mu_q(x) - \mu_q(x)))^2))$, $\mu_0^3(x^*(b_i, \sum_{q=1}^{2} (\beta_q (\max_{x \in \Omega} \mu_q(x) - \mu_q(x)))^2))$ and the maximum values of the membership functions for fulfilling the constraints $\mu_1(x^*(b_i, \sum_{q=1}^{2} (\beta_q (\max_{x \in \Omega} \mu_q(x) - \mu_q(x)))^2))$, $\mu_2(x^*(b_i, \sum_{q=1}^{2} (\beta_q (\max_{x \in \Omega} \mu_q(x) - \mu_q(x)))^2))$.

The results obtained in the work are shown in the table (see table 1).

Comparison and analysis of the results of the data presented in Table 1 gives grounds to draw the following conclusions:

1) The proposed algorithm is more efficient than the deterministic method and more accurately matches the experimental data.

2) When solving optimization problems based on the proposed algorithms, the adequacy of solving the production problem increases, since additional fuzzy information (experience, knowledge) is taken into account more fully describing the real situation without idealization.

3) The applied algorithm for solving a multicriteria decision-making problem (GK-IT) allows us to determine the membership function of the fulfillment of one or another fuzzy constraint, i.e. the degree of correctness of the resulting decisions.

The reliability of the obtained results and conclusions is confirmed by: the correctness of the research methods used, based on the scientific provisions of the theory of decision making and optimization, theories of fuzzy sets, methods of expert assessments; sufficient convergence of calculation-model (theoretical) and experimental (pilot-industrial) results of the study.

Table 1 – Comparison of the results of solving a multicriteria decision-making problem for choosing an effective OHS mode according to the proposed algorithm (GK-IT), according to a deterministic method and experimental data

No	Criterion and Constraint Values	Deterministic method (lit. data)	Proposed Algorithm (GK-IT)	Experimental data (atyrau OPS)
1.	Oil pumping volume (productivity), tons/hour, ($\tilde{y}_1$)	707	$\approx$710	709
2.	Furnace outlet temperature, ^{0}C (y_2)	48	50	50
3.	Furnace outlet pressure, kgf/cm ^{2} (y_3)	8.5	8	8.1
4.	Constraint 1 fulfillment membership function- $\mu_1^*(x^*(\beta))$	-	1.0	-
5.	Constraint 2 fulfillment membership function- $\mu_2^*(x^*(\beta))$	-	0.98	-
6.	Optimal values of operating parameters $x^* = (x_1^*,\ldots,x_4^*)$: x_1^* – furnace inlet temperature, ^{o}C;	35	33	34
7.	x_2^* – furnace inlet pressure, kgf/cm ^{2};	10,5	9.8	10
8.	x_3^* – fuel consumption, kg/hour;	27	25	26
9.	x_4^* – volume of raw materials (oil) at the furnace inlet, tons/hour;	710	710	710

Notes: (-) means that the corresponding indicators are not determined by this method. The time required to find a solution in the compared methods is the same.

Conclusion

In this work, based on a combination and modification of various optimality principles, new formulations of multicriteria decision-making problems for selecting operating modes of technological units of a main oil pipeline are proposed, and interactive algorithms for solving the problems are developed. The developed algorithms are based on the use of the idea of various compromise decision-making schemes (various combinations of the main criterion method, Pareto principles of optimality and the ideal point), modified to work in a fuzzy environment. The results of the implementation of the application of the proposed approach in practice for the selection of optimal operating modes of the oil heating station of the Uzen-Samara oil pipeline at the Atyrau point are presented based on a modification of the idea of the methods of the main criterion (for criteria) and the ideal point (for constraints).

The scientific novelty of the results of the work lies in the fact that the tasks are set and solved in a fuzzy environment without prior conversion to deterministic tasks. This provides, due to the full use of the collected fuzzy information, obtaining a more adequate solution to a complex production problem with fuzzy initial information.

The practical significance of the work is determined by the effective solution of complex production problems in conditions of multicriteria and fuzziness, which cannot be solved or are difficult to solve by traditional deterministic or stochastic mathematical methods. The advantage of the proposed approach to solving the problem is also that, depending on the production situation and the availability of initial information of various types, the decision maker is given the opportunity to select a more suitable algorithm for solving the problem from the proposed set of algorithms.

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ТЕХНОЛОГИЯЛЫҚ ЖҮЙЕЛЕРДІҢ ЖҰМЫС РЕЖИМДЕРІН ЖӘНЕ ОЛАРДЫ ШЕШУ ӘДІСТЕРІН БАСҚАРУҒА АРНАЛҒАН АНЫҚ ЕМЕС ШЕШІМДЕР ҚАБЫЛДАУ МӘСЕЛЕЛЕРІ

Айқын емес технологиялық объектілерді басқару үшін шешім қабылдау міндеттерін қою рәсімделді және алынды және оларды шешу әдістері ұсынылды. Зерттеу объектісі" ыстық " магистральдық мұнай құбырын жылыту пункттері болып табылады. Мұндай нысандар көбінесе көп критерийлікпен сипатталатындықтан және көбінесе айқын емес бастапқы ақпарат жағдайында жұмыс істейтіндіктен, тапсырмалар айқын емес ортада көп критерийлік шешім қабылдау есептері ретінде ресімделеді. Оңтайлылықтың әртүрлі принциптерін өзгерту негізінде шешілетін есептердің Жаңа математикалық тұжырымдары алынды және оларды шешудің интерактивті эвристикалық алгоритмдері жасалды. Айқын емес есептерді шешудің белгілі әдістерінен формальды айқын емес есептерді шешудің ұсынылған тәсілдерінің жаңалығы мынада: міндеттер оларды эквивалентті детерминирленген нұсқаларға айналдырмай қойылады және шешіледі, бұл бастапқы айқын емес ақпараттың жоғалуын азайтпайды және барабар және тиімді шешімдер алуға мүмкіндік береді. Атырау пунктіндегі өзен-Самара мұнай құбырын жылыту станциясының тиімді жұмыс режимін таңдау мәселесін шешу кезінде әзірленген алгоритмдердің бірін іске асыру арқылы шешім қабылдау міндеттерін шешуге ұсынылған тәсілді практикалық қолдану мысалы келтірілген.
Түйін сөздер: *айқын емес шешім қабылдау, көп өлшемді оңтайландыру, ақпарат, мүшелік функциясы, оңтайлылық принциптері, шешім қабылдаушы.*

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ЗАДАЧИ ПРИНЯТИЯ НЕЧЕТКИХ РЕШЕНИЙ ДЛЯ УПРАВЛЕНИЯ РЕЖИМАМИ РАБОТЫ ТЕХНОЛОГИЧЕСКИХ СИСТЕМ И МЕТОДЫ ИХ РЕШЕНИЯ

Формализованы и получены постановки задач принятия решений для управления нечеткими технологическими объектами и предложены методы их решения. Объектом исследования являются пункты обогрева «горячего» магистрального нефтепровода. Поскольку такие объекты часто характеризуются многокритериальностью и часто функционируют в условиях нечеткой исходной информации, задачи формализуются в виде многокритериальных задач принятия решений в нечеткой среде. На основе модификации различных принципов оптимальности были получены новые математические формулировки решаемых задач и разработаны интерактивные эвристические алгоритмы их решения. Новизна предлагаемых подходов к решению формализованных нечетких задач от известных методов решения нечетких задач заключается в том, что задачи ставятся и решаются без предварительного преобразования их в эквивалентные детерминированные варианты, что не уменьшает потери исходной нечеткой информации и позволяет получать более адекватные и эффективные решения. Приведен пример практического применения предложенного подхода к решению задач принятия решений путем реализации одного *из разработанных алгоритмов при решении задачи выбора эффективного режима работы станции подогрева нефти нефтепровода Узень-Самара в пункте Атырау.*

Ключевые слова: *нечеткое принятие решений, многокритериальная оптимизация, информация, функция принадлежности, принципы оптимальности, лицо, принимающее решение (ЛПР).*

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ВЕБ-БЕТТЕРДЕГІ ЗИЯНДЫ ЖАРНАМАЛЫҚ БАҒДАРЛАМАЛАРДЫ АНЫҚТАУДА МАШИНАЛЫҚ ОҚЫТУ АЛГОРИТМДЕРІН ПАЙДАЛАНУ

Аңдатпа: *Мақалада интернет қолданушыларының құпиялылығы мен қауіпсіздігіне айтарлықтай қауіп төндіретін веб-беттер арқылы зиянды жарнамалық бағдарламаларды тарату мәселесі қарастырылады. Веб-беттерге енгізілген зиянды жарнамалық бағдарламаларды анықтау және бейтараптандыру үшін машиналық оқыту алгоритмдерін қолдану. Деректерді өңдеу, белгілерді алу және жіктеу әдістеріне назар аудара отырып, машиналық оқыту зиянды бағдарламарларды анықтау процестерін қалай жақсарта алатынын егжей-тегжейлі талдайды. Зиянды және заңды жарнамалық мазмұнды ажыратудағы тиімділігін анықтау үшін машиналық оқытудың әртүрлі алгоритмдері, соның ішінде логистикалық регрессия, шешім ағаштары, кездейсоқ орман, аңғал Байес және ансамбльдік әдістер зерттеледі.*

Зиянды және қауіпсіз жарнама модульдері туралы деректерді қамтитын оқыту және тест үлгілерін құру әдістемесі сипатталған. Зиянды мінез-құлықтың жасырын үлгілерін анықтау үшін машиналық оқытудың әртүрлі тәсілдері, соның ішінде мұғаліммен, мұғалімсіз оқыту және терең оқыту әдістері талданады. Зерттеу нәтижелері машиналық оқыту алгоритмдерін қолдану зиянды жарнамалық бағдарламаларды жоғары дәлдікпен анықтауға мүмкіндік беретінін көрсетеді, бұл тиімдірек киберқауіпсіздік құралдарын әзірлеуге негіз бола алады. Сондай-ақ, қолданыстағы