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Arthur Gibadullin
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Information Technologies and Intelligent Decision Making Systems

Second International Conference, ITIDMS 2022
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Revised Selected Papers

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Preface

The international scientific and practical conference "Information Technologies and Intelligent Decision Making Systems" (ITIDMS 2022) was held on December 12–14, 2022, on the Microsoft Teams platform due to COVID-19.

The conference was held with the aim of developing and exchanging international experience in the field of information, digital and intellectual technologies, within the framework of which proposals were formulated for digital, intellectual and information transformation, the development of computer models and the improvement of automated and computing processes.

A distinctive feature of the conference is that it presented reports of authors from USA, Canada, Bangladesh, Uzbekistan and Russia. Researchers from different countries addressed the process of transition on the path of information and digital development, and presented the main directions and developments that can improve efficiency and development.

The conference sessions were moderated by Artur Gibadullin of the National Research University "MPEI", Moscow, Russia.

Thus, the conference facilitated scientific recommendations on the use of information, computer, digital and intellectual technologies in industry and fields of activity that can be useful to state and regional authorities, international and supranational organizations, and the scientific and professional community.

Each presented paper was reviewed by at least three members of the Program Committee in a double-blind manner. As a result of the work of all reviewers, 14 papers were accepted for publication out of the 38 received submissions. The reviews were based on the assessment of the topic of the submitted materials, the relevance of the study, the scientific significance and novelty, the quality of the materials, and the originality of the work. Authors could revise their paper and submit it again for review. Reviewers, Program Committee members, and Organizing Committee members did not enter into discussions with the authors of the articles.

The Organizing Committee of the conference expresses its gratitude to the staff at Springer who supported the publication of these proceedings. In addition, the Organizing Committee would like to thank the conference participants, reviewers and everyone who helped organize this conference and shape the present volume for publication in the Springer CCIS series.

December 2022 Arthur Gibadullin

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Contents

Algorithm for Solving the Problem of Multi-criteria Optimization of Poorly Formed Processes Based on the Construction of a Fuzzy Logic Model

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Abstract. The purpose of the research is to develop fuzzy logical models and algorithms and a software complex of fire safety on the basis of an intellectual approach. The task of the research is to develop an algorithm for solving the problem of multi-criteria optimization of poorly formed processes based on the construction of a fuzzy logic model. In this case, the mathematical model of calculating the reasonable number of operational fire-rescue units, fire extinguishing equipment and assigning them to extinguishing areas, that is, the optimization of the composition of forces and equipment in the fire, is formalized in the form of interacting objects.

Keywords: Algorithm · Fuzzy Logic Models · Fire Safety · Mathematical Model

1 Introduction

Systematic analysis of complex processes and objects, research of their modeling processes in order to optimize their parameters and manage them showed that there is an inverse relationship between the "complexity" and "accuracy" of solving the above-mentioned problems. According to this law, as the complexity of the researched objects increases, deterministic, including purely probabilistic (stochastic) methods do not provide accurate, object-friendly models of processes and, accordingly, optimization, decision-making and control models [1, 2].

This determined the relevance of working with uncertainties, including those of a subjective nature, developing new directions in mathematics: the development and formation of interval fuzzy sets and lines of possibilities [3–5].

The need for scientific research works on the development of traditional and modern methods of intellectual processing of the system is emerging due to the increase in the emergency situations occurring in the world and the material and moral damage seen in them. In this regard, scientific research is being carried out in the world aimed at the joint

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development of fuzzy logic, neural networks and evolutionary algorithms, as well as the creation of calculation algorithms, including the development of fuzzy logic models, algorithms and programs of weakly formed processes based on intellectual analysis of data [6–8].

2 Materials and Methods

The problem of multi-criteria optimization of the effective placement of firefighting units in given positions is written in the form (1) and (2):

$$\begin{gathered} z_1\left(x_{ij}^*\right) = \max_{x_{ij}\in D}\left(\sum_{i=1}^{m}\sum_{j=1}^{n} c_{ij}^1 x_{ij}\right), \\ z_2\left(x_{ij}^*\right) = \min_{x_{ij}\in D}\left(\sum_{i=1}^{m}\sum_{j=1}^{n} c_{ij}^2 x_{ij}\right), \\ \ldots\ldots\ldots\ldots\ldots\ldots \\ z_s\left(x_{ij}^*\right) = \min_{x_{ij}\in D}\left(\sum_{i=1}^{m}\sum_{j=1}^{n} c_{ij}^s x_{ij}\right), \end{gathered} \tag{1}$$

$$D = \left\{ x_{ij} \middle| \sum_{i=1}^{m} x_{ij} \le Q_{1j},\ \sum_{j=1}^{n} x_{ij} \le Q_{2i},\ x_{ij} > 0,\ i = \overline{1, m},\ j = \overline{1, n} \right\}, \tag{2}$$

Here:

n – number of objects on fire;

m – number of emergency departments;

S – number of criteria;

x_{ij} – j-resource directed from the emergency department to the i-facility; Q_{1j} – j-fire facility resource requirements;

Q_{2i} – Resources available in the i-Emergency Unit *(EU).*;

c_{ij}^s – i-s-cost (time, road, water, etc.) per unit of resources directed from the emergency department to j-fire facility.

In most cases, the limitations of parametric models consist of the mathematical description and quantitative expression of very different conditions on which a certain technical or production process depends. This diversity can be seen, in particular, in the fact that the causes influencing the changes in the quantities that help to express the corresponding changes should be viewed as independent but acting simultaneously. It is natural to represent problems of this type using several parameters. Often, only “fuzzy” information about the coefficients of a parametric model is available. The theory of fuzzy sets is used in the work as a mathematical apparatus that allows to formalize fuzzy data. S independent parameters $\lambda_1, \ldots, \lambda_S$ parametric model or S parametric problem with, is written in matrix form as follows:

$$z(x_{ij}^*) = \min_{x_{ij}\in D}\left(\sum_{i=1}^{m}\sum_{j=1}^{n} (\lambda_1 c_{ij}^1 + \lambda_2 c_{ij}^2 + \ldots + \lambda_S c_{ij}^S) x_{ij}\right), \tag{3}$$

$$D = \left\{ x_{ij} \middle| \sum_{i=1}^{m} x_{ij} \le Q_{1j},\ \sum_{j=1}^{n} x_{ij} \le Q_{2i},\ x_{ij} \ge 0,\ i = \overline{1, m},\ j = \overline{1, n} \right\} \quad (4)$$

Here: λ_s- s-parameter of the multicriteria objective function.

In the case of multi-criteria optimization, it is difficult to evaluate the optimal solution of the problem according to the set of criteria. As the most common methods in this regard, we can take the additive check and the methods evaluated by the decision maker (VAT) [9]. An algorithm for solving the problem of multi-criteria optimization of poorly formed processes was developed based on the construction of a fuzzy logic model [10, 11].

We will consider a fuzzy method to identify alternative solutions. Solving the multi-criteria optimization problem consists of the following steps [12]:

- Formation of the objective function in an ambiguous environment.
- Determining the values of the boundary conditions in an ambiguous form.
- Develop relevance function for criteria.
- Defining a "preference" base and/or rule base for criteria.
- Calculation of the value of the objective function.
- Defuzzification of the objective function.

This $\Lambda \in D_A$ are found using the following fuzzy rule inferences:

$$\bigcup_{p=1}^{k_i} \left(\bigcap_{i=1}^{S} \lambda_i = \psi_{i,jp} \ - \ \text{with weight} \right) \to z_s(\lambda*) = z_s(\lambda*). \quad (5)$$

Here $\Psi_{i,jp}$ - jp in the numbered line λ_i a linguistic term that gives the value of a variable;

w_{jp} rule weight coefficient with order number jp;

$z_s(\lambda) = z_s(\lambda*)$- fuzzy rule inference.

Ψ we consider size to be a linguistic variable that can take values ranging from "Very-Very Low" to "High". Kernel of the fuzzy variable Ψ denote as Ψ, therefore Ψ the value of the variable is "Very-Very Bad"corresponds to $\Psi = 1$, and the "Excellent" value is $\Psi = l$.

The result is a multi-criteria optimization problem $\Psi(\Lambda)$ which provides the maximum value of the discrete function $\Lambda \in D_A$ comes down to the problem of finding a vector:

$$\max_{\Lambda} \Psi(\Lambda) = \Psi(\Lambda) = \Psi \quad (6)$$

$$\Lambda \in D_\Lambda$$

Every incoming variable Ψ_{jp} will have its own relevance function with a fuzzy term. Ψ_{jp} having term λ_i relevance function of the element is as follows:

$$\mu^{jp}(\lambda_i) = \frac{1}{1 + \left(\frac{\lambda_i - b_i^{jp}}{c_i^{jp}} \right)^2}, \quad (7)$$

Here b_i^{jp}, c_i^{jp} - parameters of relevance functions.

Sugeno model of multicriteria optimization problem.

If $\lambda_1^1 = L$ and $\lambda_2^1 = L$ and $\lambda_3^1 = H$ or $\lambda_1^1 = L$ and $\lambda_2^1 = BA$ and $\lambda_3^1 = H$ **or** $\lambda_1^1 = L$ and $\lambda_2^1 = A$ and $\lambda_3^1 = A$ **or** $\lambda_1^1 = L$ and $\lambda_2^1 = H$ and $\lambda_3^1 = BA$ **or** $\lambda_1^1 = L$ and $\lambda_2^1 = H$ and $\lambda_3^1 = L$ if, then:

$$z = 14,06 + 0,0001\frac{\sum_{j=1}^{n}\mu(\lambda_1^{1j})\lambda_1^{1j}}{\sum_{j=1}^{n}\mu(\lambda_1^{1j})} - 2,9\frac{\sum_{j=1}^{n}\mu(\lambda_2^{1j})\lambda_2^{1j}}{\sum_{j=1}^{n}\mu(\lambda_2^{1j})} + 0,0001\frac{\sum_{j=1}^{n}\mu(\lambda_3^{1j})\lambda_3^{1j}}{\sum_{j=1}^{n}\mu(\lambda_3^{1j})}. \quad (8)$$

If $\lambda_1^1 = BA$ and $\lambda_2^1 = L$ and $\lambda_3^1 = H$ **or** $\lambda_1^1 = BA$ and $\lambda_2^1 = BA$ and $\lambda_3^1 = A$ **or** $\lambda_1^1 = BA$ and $\lambda_2^1 = A$ and $\lambda_3^1 = BA$ **or** $\lambda_1^1 = BA$ and $\lambda_2^1 = H$ and $\lambda_3^1 = L$ if, then:

$$z = 21,25 + 0,0001\frac{\sum_{j=1}^{n}\mu(\lambda_1^{1j})\lambda_1^{1j}}{\sum_{j=1}^{n}\mu(\lambda_1^{1j})} - 4,0001\frac{\sum_{j=1}^{n}\mu(\lambda_2^{1j})\lambda_2^{1j}}{\sum_{j=1}^{n}\mu(\lambda_2^{1j})} + 0,0001\frac{\sum_{j=1}^{n}\mu(\lambda_3^{1j})\lambda_3^{1j}}{\sum_{j=1}^{n}\mu(\lambda_3^{1j})}. \quad (9)$$

If $\lambda_1^1 = A$ and $\lambda_2^1 = L$ and $\lambda_3^1 = A$ **or** $\lambda_1^1 = A$ and $\lambda_2^1 = A$ and $\lambda_3^1 = L$ **or** $\lambda_1^1 = H$ and $\lambda_2^1 = L$ and $\lambda_3^1 = BA$ **or** $\lambda_1^1 = H$ and $\lambda_2^1 = BA$ and $\lambda_3^1 = L$ **or** $\lambda_1^1 = H$ and $\lambda_2^1 = L$ and $\lambda_3^1 = L$ if, then:

$$z = -14.0 + 70,5\frac{\sum_{j=1}^{n}\mu(\lambda_1^{1j})\lambda_1^{1j}}{\sum_{j=1}^{n}\mu(\lambda_1^{1j})} - 4,0\frac{\sum_{j=1}^{n}\mu(\lambda_2^{1j})\lambda_2^{1j}}{\sum_{j=1}^{n}\mu(\lambda_2^{1j})} + 0,0001\left[\frac{\sum_{j=1}^{n}\mu(\lambda_3^{1j})\lambda_3^{1j}}{\sum_{j=1}^{n}\mu(\lambda_3^{1j})}\right]^2. \quad (10)$$

Here:

L – Low,

BA – Below average,

A – Average,

AA – Above average,

H – High.

The problem of multi-criteria optimization of weakly formed processes can be solved based on the construction of Sugeno's fuzzy logic model.

3 Results

The above-mentioned multi-criteria optimization model was solved for the case of m = 3, n = 4 and S = 3 based on the data presented in the following Table 1.

Table 1. Objective function coefficients and resources.

	Object1	Object 2	Object 3	Object 4	Available resources (Q_{2i})
EI 1	0.6 0.1 0.2	0.7 0.2 0.1	0.3 0.3 0.1	0.8 0.1 0.1	40
EI 2	0.5 0.2 0.3	0.4 0.1 0.1	0.5 0.3 0.1	0.3 0.3 0.2	15
EI 3	0.4 0.3 0.2	0.3 0.2 0.2	0.6 0.3 0.1	0.7 0.3 0.2	30
Required resources (Q_{1j})	20	20	10	35	

Using the information in the table above, the optimization problem is solved using three different objective functions for the optimization model.

Maximization objective function with respect to water volume:

$$\begin{aligned} Z_1 &= 0.6x_{11} + 0.7x_{12} + 0.3x_{13} + 0.8x_{14} + \\ &+ 0.5x_{21} + 0.4x_{22} + 0.5x_{23} + 0.3x_{24} + \\ &+ 0.4x_{31} + 0.3x_{32} + 0.6x_{33} + 0.7x_{34}. \end{aligned} \tag{11}$$

Minimization objective function with respect to time:

$$\begin{aligned} Z_2 &= 0.1x_{11} + 0.2x_{12} + 0.3x_{13} + 0.1x_{14} + \\ &+ 0.2x_{21} + 0.1x_{22} + 0.3x_{23} + 0.3x_{24} + \\ &+ 0.3x_{31} + 0.2x_{32} + 0.3x_{33} + 0.3x_{34}. \end{aligned} \tag{12}$$

Minimization objective function with respect to path:

$$\begin{aligned} Z_3 &= 0.2x_{11} + 0.1x_{12} + 0.1x_{13} + 0.1x_{14} + \\ &+ 0.3x_{21} + 0.1x_{22} + 0.1x_{23} + 0.2x_{24} + \\ &+ 0.2x_{31} + 0.2x_{32} + 0.1x_{33} + 0.2x_{34}. \end{aligned} \tag{13}$$

General objective function $Z = -\lambda_1 z_1 + \lambda_2 z_2 + \lambda_3 z_3$ will be in the form of.

When a multi-criteria optimization problem is solved considering a single objective function, for a chosen objective function λ_S the appropriate parameters of the vector are taken as 1 and the others are ignored, i.e. taken as $0.\lambda_S$ the sum of the values of the parameters of the vector is required to be equal to 1 based on the rule of the weight coefficient. In this case $\lambda_1,\ldots,\lambda_S$ vector value is defined as:

$$\lambda_1 = 1,\ \lambda_2 = 0,\ \lambda_3 = 0\,, \tag{14}$$

For the paramaeters value of optimization is equal to $z_2 = 56.5$ for this case values of x_{ij}-are given in the Table 2.

Table 2. Values of x_{ij} for the parameters $\lambda_1 = 1,\ \lambda_2 = 0,\ \lambda_3 = 0$

	Object1	Object 2	Object 3	Object 4	Available resources (Q_{2i})
EI 1	5	20	0	15	40
EI 2	15	0	0	0	15
EI 3	0	0	10	20	30
Required resources (Q_{1j})	20	20	10	35	

For the second target function z_2 λ_S the values of the vector are defined as follows:

$$\lambda_1 = 0,\ \lambda_2 = 1,\ \lambda_3 = 0\,, \tag{15}$$

Value of the optimization model for the parameters is equal to, for this case x_{ij}-values of are given in Table 3.

Table 3. Values of x_{ij} for the parameters $\lambda_1 = 0,\ \lambda_2 = 1,\ \lambda_3 = 0$

	Object1	Object 2	Object 3	Object 4	Available resources (Q_{2i})
EI 1	5	0	0	35	40
EI 2	0	15	0	0	15
EI 3	15	5	10	0	30
Required resources (Q_{1j})	20	20	10	35	

For the third target function z_3 λ_S the values of the vector are defined as follows:

$$\lambda_1 = 0,\ \lambda_2 = 0,\ \lambda_3 = 1\,, \tag{16}$$

The value of the optimization model for the parameters is equal to $z_3 = 10.5$, for this casevalues of x_{ij}-are given in Table 4.

Table 4. Values of x_{ij} for the parameters $\lambda_1 = 0,\ \lambda_2 = 0,\ \lambda_3 = 1$

	Object1	Object 2	Object 3	Object 4	Available resources (Q_{2i})
EI 1	0	5	0	35	40
EI 2	0	15	0	0	15
EI 3	20	0	10	0	30
Required resources (Q_{1j})	20	20	10	35	

For the general target function Z the values of the vector λ_S are defined as follows:

$$\lambda_1 = 0.5,\ \lambda_2 = 0.2,\ \lambda_3 = 0.3\,, \tag{17}$$

General purpose function $Z = -\lambda_1 z_1 + \lambda_2 z_2 + \lambda_3 z_3$ will look like this:

$$\begin{aligned} Z = 0.22x_{11} + 0.28x_{12} + 0.06x_{13} + 0.35x_{14} + \\ +0.12x_{21} + 0.15x_{22} + 0.16x_{23} + 0.03x_{24} + \\ +0.08x_{31} + 0.05x_{32} + 0.21x_{33} + 0.23x_{34}, \end{aligned} \tag{18}$$

The value of the optimization model for these coefficients is equal to, for this casethe values of x_{ij}-are given in Table 5.

Table 5. x_{ij} values of for the parameters $\lambda_1 = 0.5,\ \lambda_2 = 0.2,\ \lambda_3 = 0.3$

	Object1	Object 2	Object 3	Object 4	Available resources (Q_{2i})
EI 1	5	20	0	15	40
EI 2	15	0	0	0	15
EI 3	0	0	10	20	30
Required resources (Q_{1j})	20	20	10	35	

Table 6. x_{ij} values for the parameters $\lambda_1 = 0.8,\ \lambda_2 = 0.1,\ \lambda_3 = 0.1$

	Object1	Object 2	Object 3	Object 4	Available resources (Q_{2i})
EI 1	5	20	0	15	40
EI 2	15	0	0	0	15
EI 3	0	0	10	20	30
Required resources (Q_{1j})	20	20	10	35	

λ_S when other values of the vector are specified:

$$\lambda_1 = 0.8, \lambda_2 = 0.1, \lambda_3 = 0.1, \tag{19}$$

General objective function $Z = -\lambda_1 z_1 + \lambda_2 z_2 + \lambda_3 z_3$ will look like this:

$$\begin{aligned} Z = 0.45x_{11} + 0.53x_{12} + 0.20x_{13} + 0.62x_{14} + \\ +0.35x_{21} + 0.30x_{22} + 0.36x_{23} + 0.19x_{24} + \\ +0.27x_{31} + 0.20x_{32} + 0.44x_{33} + 0.51x_{34}, \end{aligned} \tag{20}$$

The value of the optimization model for the coefficients is equal to, for this case x_{ij}-the values of are given in Table 6.

This sequence is continued, the values of the objective function are found for the remaining parameters of the vector λ_S, and the training sample presented in Table 7 for the fuzzy logic model is generated as follows.

Table 7. Fuzzy knowledge base of multi-criteria optimization problem.

λ_1	λ_2	λ_3	Z
1.00	0.00	0.00	56.50
0.00	1.00	0.00	14.00
0.00	0.00	1.00	10.50
0.50	0.20	0.30	28.00
0.80	0.10	0.10	42.00
0.34	0.01	0.65	10.53
0.64	0.02	0.34	31.04
0.85	0.07	0.08	45.65
…	…	…	…

4 Conclusion

The scientific significance of the research results is based on the improvement of the classification model algorithm based on the matrix representation of Sugeno and Mamdani. Explained by application. An algorithm for solving the problem of multi-criteria optimization of poorly formed processes was developed based on the construction of a fuzzy logic model. This made it possible to solve the problem of multi-criteria optimization of effective placement of fire rescue units in given positions.

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