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**Article**

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# DEVELOPMENT OF DECISION APPROVAL RULES IN MULTICHANNEL DECISION-MAKING SYSTEMS

*The research is devoted to the development of rules for the coordination of decisions in multichannel decision-making systems. Systems are considered that in an automated continuous mode process incoming signals from different channels and, on their basis, make the final decision. One of the most problematic stages in the operation of such systems is their own coordination of solutions received from different channels. There may be cases where different channels provide signals with opposite values. Then the choice of the decisive solution should depend on the reliability of the channels under consideration.*

*The object of research is the processes that take place during the coordination of decisions in multichannel decision-making systems. The development and implementation of such systems will allow in an automated mode to generalize the solution obtained through different channels, to increase the reliability and efficiency of the systems as a whole.*

*During the study, the following methods were used:*

*– a systematic approach – when analyzing the structure and functioning of multichannel one-stage decision-making systems;*

*– method of mathematical modeling – for formalizing the problem of coordinating decisions in multichannel decision-making systems;*

*– method of analysis – when developing rules for agreeing decisions.*

*The authors analyzed the structure of a one-stage multichannel decision-making system. The case is considered when the channels, based on the initial data entering the system, decide on the presence or absence of a certain fact. That is, the channels send signals from the set {True, False}.*

*In the study, decision rules for the coordination of decisions were developed, taking into account not only the signals received from different channels, but also the reliability of the channels themselves. As is usual in decision theory, different rules can give different results for the same initial data. The choice of the decision rule depends on the decision maker, its personal psychological qualities and the scope of the system.*

**Keywords:** *decision coordination, decision rule, one-stage multichannel decision-making system, channel reliability.*

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## 1. Introduction

Automated decision-making systems are part of medical, transport, military, household and other technical complexes. The development of models and methods of data mining allowed them to be put on a par with systems in which a competent expert analyst plays a key role. The mathematical basis of such systems is formed by methods and algorithms for data mining, including methods of pattern recognition, identification, etc. Along with the high accuracy and reliability of automated systems, they also have a number of other advantages, including stability in operation and the possibility of continuous operation. The use of automated decision-making systems allows to reduce the time for making a decision, ensure the possibility of round-the-clock data analysis, as well as reduce the costs associated with the involvement of expert analysts. However, the implementation of complex artificial intelligent systems in socially important areas such as aviation, public safety, health care can be associated with certain difficulties. The internal processes and processes for learning complex machine systems such as deep neural networks commonly used to analyze images with high fidelity are not well understood. Therefore, relying on such systems of critical decisions can be considered risky and unjustified by the general public. For example, it has been noted that sometimes machine learning methods and algorithms can cause errors or unexpected results that are difficult to explain, evaluate and fix [1, 2].

There is also an increase in the cost of errors in critical decision-making areas, such as the cost of diagnostic errors in primary health care, which have been found to significantly contribute to the overall health care costs of the population [3, 4]. Similar trends have been found in other areas where complex solutions are required by the operating environment. Thus, along with the development of data mining methods for obtaining new data and knowledge, it is also important to develop methods for coordinating decisions obtained in various ways to increase the reliability and efficiency of automated decision-making systems.

## 2. The object of research and its technological audit

*The object of research* is the processes that take place during the coordination of decisions in multichannel decision-making systems. The development and implementation of such systems will allow in an automated mode to generalize the solution obtained through different channels, to increase the reliability and efficiency of the systems as a whole.

## 3. The aim and objectives of research

*The aim of research* is to develop rules for coordinating decisions in multichannel decision-making systems, the ultimate purpose of using which is to obtain information about the appearance or absence of a certain fact.

The development of such methods will allow increasing the number of channels in multichannel receiving systems and making the final decision taking into account the reliability of the channels included in the system.

To achieve this aim, the following objectives are set:

1. To analyze the structure of a one-stage multichannel decision-making system.

2. To develop such rules for coordinating decisions in systems that would take into account both the decisions made by the channels and the reliability of the channels themselves.

## 4. Research of existing solution to the problem

The decision problem can be reduced to choosing from a set of acceptable options. Analysis of literature sources shows that an important problem at the decision-making stage is the coordination of decisions obtained from different sources [5]. Moreover, the human expert remains an important source of solutions. Expert judgment processing techniques have been extensively studied in many studies. In [6], a method of pairwise comparison of expert opinions was developed. The works [7, 8] considered fuzzy and other methods of processing expert assessments and established the rules for creating common solutions. Studies [9, 10] contain hybrid decision-making methods based on expert and objective data. In [11], methods for determining the group ranking of incomplete expert conclusions were considered. Another group of works discussed methods for assessing the competence of experts [12, 13]. The problem of finding an optimal solution is approached as a «game with nature», where a number of methods and criteria were developed [14, 15]. The choice of criteria for making decisions usually depends on the decision maker, analysts and the owner of the problem, and depends on such subjective characteristics as the level of optimism, risk tolerance, etc. Objective factors are also taken into account that describe the area to which the decision belongs, such as: confidence, risk tolerance, priority and importance of the decisions made.

An interesting and promising issue remains the issue of making a «collective» decision in the case when the options for decisions, along with competent experts, produce software modules for data analysis. In such cases, an important step is the choice of a rule for agreeing decisions, taking into account the competence of experts and the reliability of channels to ensure the effectiveness of the decision-making system as a whole.

## 5. Methods of research

During the study, the following methods were used:

– systematic approach – when analyzing the structure and functioning of multichannel one-stage decision-making systems;

– method of mathematical modeling – for formalizing the problem of coordinating decisions in multichannel decision-making systems;

– method of analysis – when developing rules for agreeing decisions.

## 6. Research results

By a multichannel one-stage decision-making system, let's mean a system, to which a set of data is entered, after the analysis of which it is necessary to draw a conclusion about the appearance or absence of a certain signal (fact or phenomenon). The system structure has several channels for data analysis. Channels can be software implementations of data mining methods. Also, some solutions can be produced by competent experts. After all the channels have analyzed the input data and come up with a solution, the system, using the decision rule for coordinating decisions, makes the final decision on the appearance or absence of the desired signal.

A formalized multichannel one-stage decision-making system can be described as follows. Let a system be given, consisting of $N$ channels $C_1$, $C_2$,..., $C_N$, each of which is characterized by a reliability factor $A_1$, $A_2$,..., $A_N$. Let the specified system receive data $\underline{X}$ as input, and each channel generates a solution $C_i(X)$, $i=\overline{1,N}$, and $C_i(X)\in$ {True, False}. Further, using the decision rule for the coordination of decisions $D(X)=D(C_1(X),C_2(X),...,C_N(X))$, the final decision $D(X)$ is made, which is the result of the system operation.

The structure of a multichannel one-stage decision-making system is shown in Fig. 1.

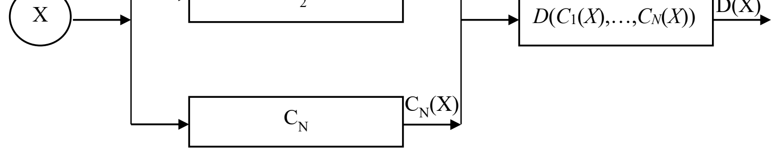


**Fig. 1.** Structural and functional diagram of a one-stage multichannel decision-making system

The following decision rules are proposed for making a decision:

1. The rule for taking into account the total reliability. The decision is made as follows:

$$D(X)=\begin{cases}\text{True, if} \sum\limits_{i=\overline{1,N}:C_i(X)=True} A_i \geq \sum\limits_{i=\overline{1,N}:C_i(X)=False} A_i;\\ \text{False, otherwise.}\end{cases} \quad (1)$$

According to this rule, the solution is selected, the total reliability of which is the highest.

2. The rule for taking into account the difference in the reliability of the channels. The decision is made as follows:

$$D(X)=\begin{cases}\text{True, if} \max\limits_{i=\overline{1,N}:C_i(X)=True} A_i - \max\limits_{i=\overline{1,N}:C_i(X)=False} A_i \geq \Delta;\\ \text{False, otherwise,}\end{cases} \quad (2)$$

where $\Delta \in (-1, 1]$ – threshold value of reliability.

The function takes on the value True if the total reliability of the channels that have taken the same value is dominated by the total reliability of those channels that have taken the opposite value for a given threshold Δ.

3. Rule for voting channels. Let's introduce the function:

$$\chi(C_i(X))=\begin{cases}1, \text{ if } C_i(X)=\text{True};\\ 0, \text{ if } C_i(X)=\text{False};\end{cases} \quad i=\overline{1,N}. \quad (3)$$

Then the decision is made as follows:

$$D(X)=\begin{cases}\text{True, if } \sum\limits_{i=1}^{N}\chi(C_i(X)) \geq \Delta;\\ \text{False, otherwise,}\end{cases} \quad (4)$$

where $\Delta \in (-1, 1]$ – threshold value for the number of votes.

The rule makes a decision taking into account the number of channels that have identified the specified condition (accepted the value True).

4. Determination of the average value of reliability. The decision on this rule is made as follows:

$$D(X)=\begin{cases}\text{False, if } \sum\limits_{i=1}^{N}\chi(C_i(X))=0;\\ \text{True, if } \sum\limits_{i=1}^{N}\chi(C_i(X))=N;\\ \text{True, if } \dfrac{\sum\limits_{i=\overline{1,N}:C_i(X)=\text{True}} A_i}{\sum\limits_{i=1}^{N}\chi(C_i(X))} \geq \dfrac{\sum\limits_{i=\overline{1,N}:C_i(X)=\text{False}} A_i}{N-\sum\limits_{i=1}^{N}\chi(C_i(X))};\\ \text{False, otherwise.}\end{cases} \quad (5)$$

This rule makes it possible to make decisions based on comparing the average values of the reliability of the channels that detected or did not find a given signal.

As a rule, the choice of the decision-making function depends on the specific task or scope of the system. To improve the flexibility and versatility of the system, the option to pre-configure the system with a decision-making function from a predefined standard set can be useful to support a wide range of tasks and programs. In most of the proposed functions, channel reliability decision making plays a key role in final decision making.

## 7. SWOT analysis of research results

*Strengths.* The strengths of this study are that the developed rules allow to expand the number of channels for data processing and make decisions, taking into account their reliability. This makes the system flexible and adaptable to the needs of the application.

*Weaknesses.* The weaknesses of the study are that, as in all decision-making systems, the final decision depends on the choice of the decision rule for agreeing decisions. Different rules can usually give different results. Thus, the reliability and efficiency of the system depends primarily on the characteristics of the decision maker and its choice to apply a specific decision rule.

*Opportunities.* The developed rules can be successfully applied in automated decision-making systems in various spheres of human activity. Systems of this type can, at some stages, replace expert analysts in medicine, economics, etc. This will reduce the cost and speed up the decision-making process in general.

*Threats.* An important stage in setting up the operation of a multichannel decision-making system is to determine the reliability of the channels. The effectiveness of the decisions made depends on the correctness of the specified reliability coefficients.

## 8. Conclusions

1. The analysis of the structure of a one-stage multichannel decision-making system has been carried out. It is noted that software implementations of relevant data mining methods can be used as channels. Competent experts can also be one of the sources of solutions. A structural and functional diagram of systems of a given type has been developed.

2. The rules for the coordination of decisions in one-stage multichannel decision-making systems have been developed. The rules are based on a comparison of the solutions that submitted the channels and the reliability of these channels. The choice of rule depends on the scope and the owner of the problem or the decision maker. The developed rules will make it possible to generate effective solutions in an automated mode without the additional involvement of experts.

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