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Original Research

Real-time monitoring and diagnostics of the person’s emotional state and decision-making in extreme situations for healthcare

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Abstract: Monitoring and diagnosing the emotional state is important for varied professional groups, especially, those involve in hazardous work, risks, and high responsibility (pilots, astronauts, miners, sailors, firefighters, military personnel, law enforcement officers, etc.). These professions are definitely extreme. Moreover, the number of these professions and people engaged in them is constantly increasing. Unfortunately, disorders of the emotional state are not easily recognized by visible symptoms, so prompt remote diagnosis and monitoring of a person's emotional state is important, especially in conditions of complex geography, lack of transportation and mobility of patients, reduced financial resources, or lack of medical staff. In many cases, effective supports from various participants involved in a difficult situation that could become dangerous are required to make a timely decision. The authors, who have aviation experience in operational detection of deviations in the pilot's emotional state and decision making under risk, propose to apply the concept of mental activity, which is based on the property of the mind to slow down or speed up the flow of subjective time in relation to the real one, for the monitoring and diagnosing the emotional state of a person. For the timely detection of a hazardous emotional state of a person in an extreme situation, the phase plane method is used, the essence of which is to build phase trajectories for differential equations in the coordinate system. The identification of a person's emotional state in real time is based on the variance analysis of the models of spontaneous (optimal), emotional and rational activities. The deformity of the emotional state is determined using a priori person’s models based on the actual material of a posteriori research of the accident investigations. The Nyquist criterion is used to measure the functional stability of a person. The method of real-time diagnostics of the person’s emotional state is presented. A software “Diagnostics of the emotional state of a human-operator” is developed.

The problem of effective monitoring and diagnostics of a person's emotional state can be solved with the help of an Intelligent Remote Monitoring System (IRMS) built on the basis of dynamic modeling principles, when the subsystems are formalized in the form of transfer functions. A person is considered as a control object, and the monitoring and diagnostics of the emotional state are based on the analysis of the phase portrait obtained by the control device. The conceptual model and the functional diagram of medical IRMS are worked out. The algorithm for monitoring and diagnosing the person’s emotional state is presented. Mikhailov and Nyquist criteria are used to determine the IRMS stability; Mikhailov and Nyquist hodographs are built. IRMS is proposed for monitoring the emotional

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state of a person in medicine, sports, treatment, and for automated monitoring of persons in hazardous environments, for example, in an aeroplane (passengers), in a smart home (people), in medicine (patients), etc. Prompt monitoring and diagnosis enables timely adjustment and improvement of a person's emotional state and prevents the development of an extreme situation towards worsening.

Based on the objective-subjective collaborative decision-making method under uncertainty, the problem of urgent delivery of medical cargo using UAV from the point of departure to the destination is solved. The optimal decision with minimum risk and maximum safety according to the Wald-Wald, Wald-Laplace, and Wald-Hurwitz criteria and with the consideration of all participants' opinions on UAV transportation, is found. Based on the dynamic programming method, the task of finding a route with minimum cost is solved when it is necessary to urgently deliver medicines to a seriously ill patient using UAV.

Keywords: Collaborative decision-making, Dynamic modeling, Dynamic programming, Emotional experience, Functional stability, Intelligent Remote Monitoring System, Mikhailov hodographe, Nyquist hodographe, Type of activity, Phase trajectory, Variance analysis, Uncertainty

Introduction

Currently, the probability of extreme situations in the world is increasing, and people are increasingly exposed to them. There is a tendency for some people to consciously seek to live through such experiences by taking risks and creating extreme situations. The modern pace and rhythm of our lives can cause mental tension in people, the extreme form of which is stress. Situations and factors that lead to its occurrence are referred to as extreme. Working in extreme conditions implies high risk, the need to make an appropriate decision, great responsibility for the task and the presence of unforeseen obstacles. Under extreme working conditions, the usual work and rest schedule is often disrupted [1]. All this places increased demands on the monitoring and diagnosis of a person's emotional state.

Severe emotional and physical stress creates the conditions for mental and somatic disorders and, in some cases, suicide. Under such extreme working conditions, it is important that a person's emotional state is stable without stress, as there is a risk of emotional exhaustion (or emotional burnout) [2, 3]. Emotional burnout syndrome has been included in the International Classification of Diseases [4], which only increases its importance for personal and professional development. Emotional exhaustion is characterized by constant physical, psychic, and moral fatigue, insomnia, headaches, eating disorders, loss of interest in favorite activities, irritability and stress [5].

People in an emergency situation must be able to constantly monitor their condition, make quick decisions, evaluate the situation appropriately, and sometimes even be able to sacrifice their lives in an emergency [6]. All this requires considerable intellectual effort and emotional stability.

Many professions work under extreme conditions: pilots, astronauts, miners, sailors, firefighters, military personnel, police officers, etc. These professions are definitely extreme. Moreover, the number of such professions and people engaged in them is constantly increasing.

Under extreme conditions, a person's usual work and rest schedule is often disrupted. In severe extreme situations, mental and other overloads reach the limits beyond which fatigue, nervous exhaustion, impaired performance, affective reactions and psychogenics (pathological states) occur. Extreme situations are dangerous for people's life, health and well-being. They sometimes occur in the course of normal production activities and lead to so-called occupational stress [1, 7].

Extreme situations can be regulated and unregulated, planned and situational, “regular” and “emergency”. In their most general form, they are divided into four groups [7, 8]:

1) caused by extraordinary conditions (natural disaster, natural or man-made catastrophe, war, mass terrorist attacks, etc.);

2) of daily life (fire, criminal attack, acute lack of time, the need to solve several equally important tasks at the same time), i.e. those that occur in everyone’s life;

3) related to potentially dangerous hobbies (mountaineering, scuba diving, high-speed driving, etc.);

4) work-related, professional – caused by the performance of professional duties. Many types of work that contain elements of industrial and occupational risk (pilots, astronauts, miners, sailors, etc.), as well as the official activities of the military, policemen, firefighters and rescuers, are associated with risks to life and health.

The following types of extreme situations can be distinguished in people's professional activities [8, 9]:

1) short-term – associated with the need to act under severe time pressure, at the fastest possible pace, with a high level of organization, and with a great psychological burden (participation in a disaster relief, rescue operations, detention of a criminal or a military operation);

2) long-term – psychologically stressful activities for a long time (tension in the work of operators of chemical production facilities, nuclear power plants, the process of detecting and investigating a crime);

3) caused by “uncertainty” – requires a decision in the presence of alternative, subjectively equally significant options for behavior (performance or non-performance of official duties under difficult conditions, reporting official negligence or illegal behavior of a person or maintaining on good terms with him/her, family conflict, etc.);

4) a situation that requires constant readiness for action – staying in monotonous, little-changing conditions in anticipation of extreme changes (duty, staying at a military checkpoint);

5) due to the receipt of probably unreliable information – requires emergency action if there is no confidence in the reliability of the information received (reports of a possible accident, disappearance of a person, taking precautionary measures, etc.);

6) caused by subjective circumstances, i.e. by the employee himself or herself (distraction or inattention, unprofessional behavior, etc.).

The analysis of workplace situations with tragic consequences shows that numbness (stupor) in the face of a real danger to life usually leads to the death of a person. But its occurrence is not accidental, it is caused by a lack of readiness to act appropriately, fear of danger due to the lack of experience (“inexperience”), cowardice and cowardice as stable character traits, and generally by, a low level of professional and psychological training or professional unsuitability

In case of insufficient level of volitional regulation of behavior when performing professional actions with a high degree of responsibility, which require the search for unusual ways out of a tense situation, the following phenomena can be observed: reduced coordination and accuracy of movements, slowed reaction, confusion, violation of the logic of thinking, reduced critical thinking, perceptual and attentional disorders up to the loss of orientation in time and space (“tunnel vision”). In particular, approximate 40% of law enforcement officers in extreme situations were guided by their moral principles, 32% were guided by the requirements of the law, and 8% defined their behavior as determined by self-preservation. Insufficient psychological preparedness to act in difficult conditions was reported by 20% of respondents whose behavior seemed to be orderly [8]. According to the surveys, only 10-25% of people in an extreme situation can take quick and effective action. About 65-80% of people hesitate and act in a shocked and confused manner. The remaining 10-15% exhibit severe, distressing behaviors, including distraction, crying, paralyzing fear and tantrums [10].

Special working conditions place increased demands on a working person, lead to errors and interruptions at work due to emotional distress, and adversely affect a person's performance and health.

Unfortunately, disorders of emotional state are not easy to be recognized by visible symptoms [6, 9], so prompt remote diagnosis and monitoring of a person's emotional state is important, especially in difficult geographical conditions, lack of transport and mobility for patients, reduced financial resources or lack of medical staff.

In many cases, to make an operational decision, it is necessary to have an effective support from various participants in a complex situation that may develop into a dangerous one. The global concept of Air Traffic Management [11] provides for collaborative decision-making (CDM) amongst all participants involved in aviation operation based on the exchange of information about the aircraft flight and its handling at the airport [12]. The implementation of CDM requires the use of an up-to-date informational environment based on the concepts of System Wide Information Management (SWIM) and Flight and Flow Information for a Collaborative Environment (FF-ICE) [12, 13].

CDM models were first considered by the authors in aviation systems to find an optimal solution in emergencies involving many different aviation actors (pilots, drone operators, flight dispatchers, air traffic controllers, etc.) on whom the overall outcome of the decision depends. However, specialists from other areas, such as engineers, emergency and rescue personnel as well as medical staff can also be involved in the CDM. For example, in an emergency that a pilot or passenger becomes incapacitated during the flight, digital medicine and telemedicine are used to seek qualified medical advice (Figure 1) [14, 15].

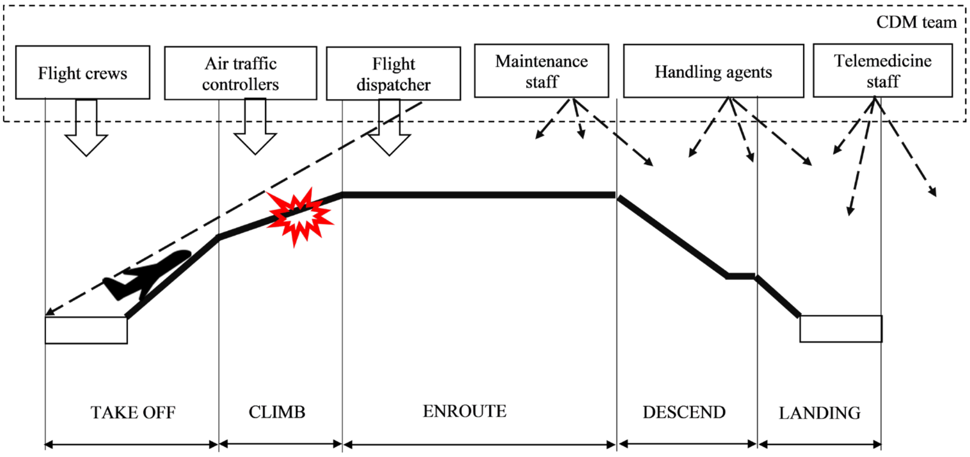


Figure 1. CDM between aviation specialists in the extreme situation

Human failure as a medical failure is compared to the acceptable failure rate of other systems critical to flight safety, such as aircraft engines. In the process of modeling the "pilot failure" emergency, the recommendations of the "Two-Link Rule" Flight Crew Training Manual (FCTM) and the Quick Reference Handbooks (QRH) were used [15-17]. Thus, most aircraft are multi-crewed ones, with two pilots participating in the flight. If the risk of an unsafe flight ending increases ("pilot incapacitation"), the second pilot receives support from autopilot/auto assistance systems and may also receive some support from other flight participants. When modeling CDM in an emergency "pilot incapacitation", the main participants are pilots, controllers, and telemedics/doctors [18].

The problem of effective real-time monitoring of a person's emotional state can be solved with the help of a modern Intelligent Remote Monitoring System (IRMS), which enables the monitoring and diagnosis of the emotional state based on the analysis of the person's phase portrait.

The objectives of this work are:

- to analyze the methods for measuring a person's emotional state;
- to design a medical IRMS for monitoring and diagnosing a person's emotional state;
- to work out the non-stochastic CDM models in the delivery of urgent medical cargo using UAV;
- to find a route with minimum cost for the transportation of urgent medical cargo using UAV.

Analysis of methods for measuring the person's emotional state

Today, there are quite a few diagnostic tools for examining the emotional sphere of a person. This is because emotion itself does not have its product, and can therefore only be studied indirectly. It can be said that each specific method for diagnosing the emotional sphere of a personality has one main component at its core, through the prism of which the emotional state is assessed. That is, each specific technique registers a particular emotion or the general emotional state of a person based on a particular criterion (change in behavior, facial expressions, choice of color, drawing details, choice of a specific picture, etc.) In general, therefore, according to the criterion of the parameter based on the emotion registered, all diagnostic methods can be divided into six main types:

- diagnostics based on the answers to questions (test methods);
- diagnostics based on the color selection;
- diagnostics based on the auditory criteria (speech rate, spectral and intonation indicators);
- diagnostics based on the behavioral changes (movements, facial expressions, etc.);
- diagnostics based on a picture, etc.

The most common methods of diagnosing the emotional state of a person are based on the answers to questions and color selection.

The most well-known tests for diagnosing emotions are the Differential Emotions Scale by C.E. Izard [19, 20] and the Self-Esteem Scale by A. Wessman and D. Ricks [21]. Both tests are based on the same principle. The methodology consists of a list of known emotional states and statements about them, which the test subject must evaluate. As a result, the sum of points is calculated according to the corresponding scheme and the dominant emotion or emotional state is determined.

The most famous method for determining a person's emotional state through the prism of color is the M. Luscher test [22]. In this method, the test person arranges 8 colored cards in a sequential row. After that, the current emotional state is determined according to the author's interpretation of the particular position of each color and the combination of colors in the entire row.

Remote monitoring and diagnosis of a person's emotional state is part of remote eHealth [23-25]. This has become possible thanks to the development of sensors, Wireless Sensor Networks (WSN), and other emerging technologies such as Wireless Body Area Network (WBAN) and the Internet of Things (IoT) [26-31]. For remote monitoring and diagnosis of emotional state, the most acceptable indicators are tremor, kinematics (reproduction of a specific range of motion), reflexometry (measurement of sensorimotor reaction times), voice, facial expressions, iris changes, perspiration, finger skin temperature, blood pressure, heart rate and skin conductance.

The assessment of the emotional and functional state based on the reviewed methods allowed the design of several diagnostic instruments that are recommended for use in professional, personal and group examinations. The most well-known among them are Kirlian bioelectrography, ROFES functional and emotional state assessment recorders, fitness trackers and smartwatches.

The Kirlian bioelectrography device [32] works on the principle of visualizing discharges. The nature of the radiation from fingerprints make it possible to determine the state of a person and draw a preliminary conclusion. The ROFES registrar [33] uses the MS7 biologically active point, which is stimulated by a microcurrent and analyzes the reactions to the stimulation. In addition to neuroses, stress levels, irritability and overstrain, the device's software evaluates 17 major systems and organs so that it can be used for regular monitoring of physical status. Fitness trackers [34] and smartwatches [35] can monitor physical activity on a daily basis with a pedometer and heart rate monitor. It is currently not possible for them to fully monitor the emotional state.

API/SDK uses AI algorithms to obtain information about the emotional state from the physiological sensors [36]. It uses common parameters such as heart rate and skin conductance to measure emotions. The technology can detect extreme triggers and levels of excitement in real time and offline. It can also timestamp the start and end of an emotional event for preliminary investigation. Long-term analysis of typical emotional responses throughout the day is also possible to note when they occur most frequently.

A system was developed for real-time monitoring of the emotional state, for diagnosing the intensity of emotional experiences in extreme situations and for determining the functional stability of the pilot to predict the development of the flight situation [37].

Thus, a recorder of a person's emotional state is a device that compares the body's reactions to standard actions with benchmark settings. Benchmark settings are determined through long-term studies of specific categories of people with a known emotional state. The device has a display that shows the measured values, which can be compared with typical settings to indicate the state or degree of abnormality. By targeting the software to a specific operating platform, its capabilities can be enhanced with comments and advice. The USE-CASE diagram (Figure 2) can represent the basic script of interaction between the device and the user's computer. The "Interrupt" operation is necessary to restore or change the state of a person within a certain time.

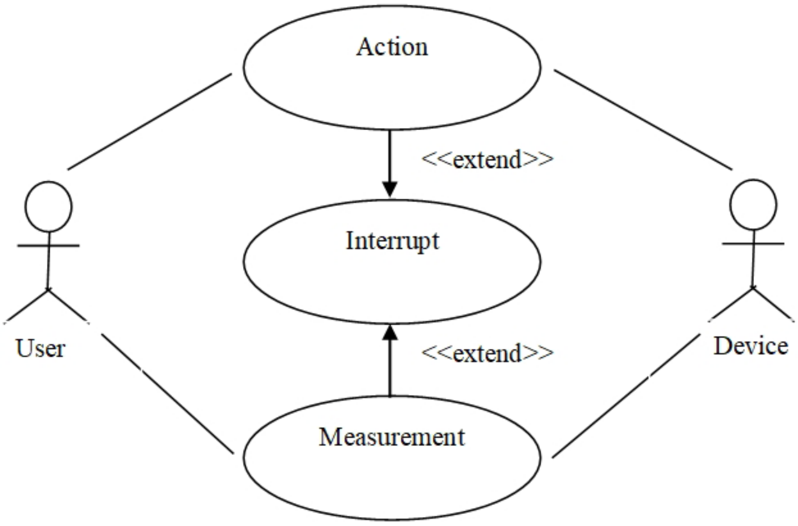


Figure 2. The main scenario for processing measurement results

IRMS is proposed for monitoring the emotional state of people in medicine, sports, treatment and automated monitoring of persons in hazardous environments, for example, in an aeroplane (passengers), in a smart home (people), in medicine (patients), etc. The core of the control system is to define and describe the relationships and dependencies between the key factors, options and features of the control device and the control object (person).

Automated system for remote monitoring and diagnosis of a person's emotional state

Remote monitoring and diagnosis of a person's emotional state

The authors, who have experience in aviation in the operational identification of deviations in the pilot's emotional state and in decision-making under risk, propose to apply the concept of mental activity for the monitoring and diagnosis of the person's emotional state based on the property of the mind to slow down or speed up the flow of subjective time in relation to real time. This is reflected in the deformity of emotional experience in the form of a transition from optimal (spontaneous) to hazardous (rational or emotional) types of human activity in extreme situations and a violation of a person's functional stability [37].

The spontaneous (optimal) type of activity is characterized by the accuracy and timeliness of a person's actions in non-standard situations. Low emotional tension, a person's transition to a potentially hazardous psychic activity: emotional type of activity – anticipatory actions in relation to real time and reasonable type of activity – delayed actions in relation to real time.

Spontaneous activity is mainly generated by automatic psychic processes and is characterized by the correctness of the person's actions in the context of previous experience. These actions are coordinated in time and space between the real (physical) and subjective (psychic) processes or are delayed by no more than two seconds. The person's actions in the optimal (spontaneous), emotional and reasonable modes are defined by the phase trajectory of the deviation of the measured indicators (blood pressure, heart rate, etc.). For example, the pilot's actions are determined by the phase trajectory of the aileron deflection and the direction of the rudder.

For timely detection of a hazardous emotional state of a person in an extreme situation, it is proposed to use the phase plane method [38], the remedy of which is to build phase trajectories for differential equations in the coordinate system: the deviation of the monitored parameter *x* and the rate of its change $y=dx/dt$. To do this, it is necessary to perform the inverse conversion: to obtain the equations of the person's movements for spontaneous, emotional and reasonable control from the existing phase portraits.

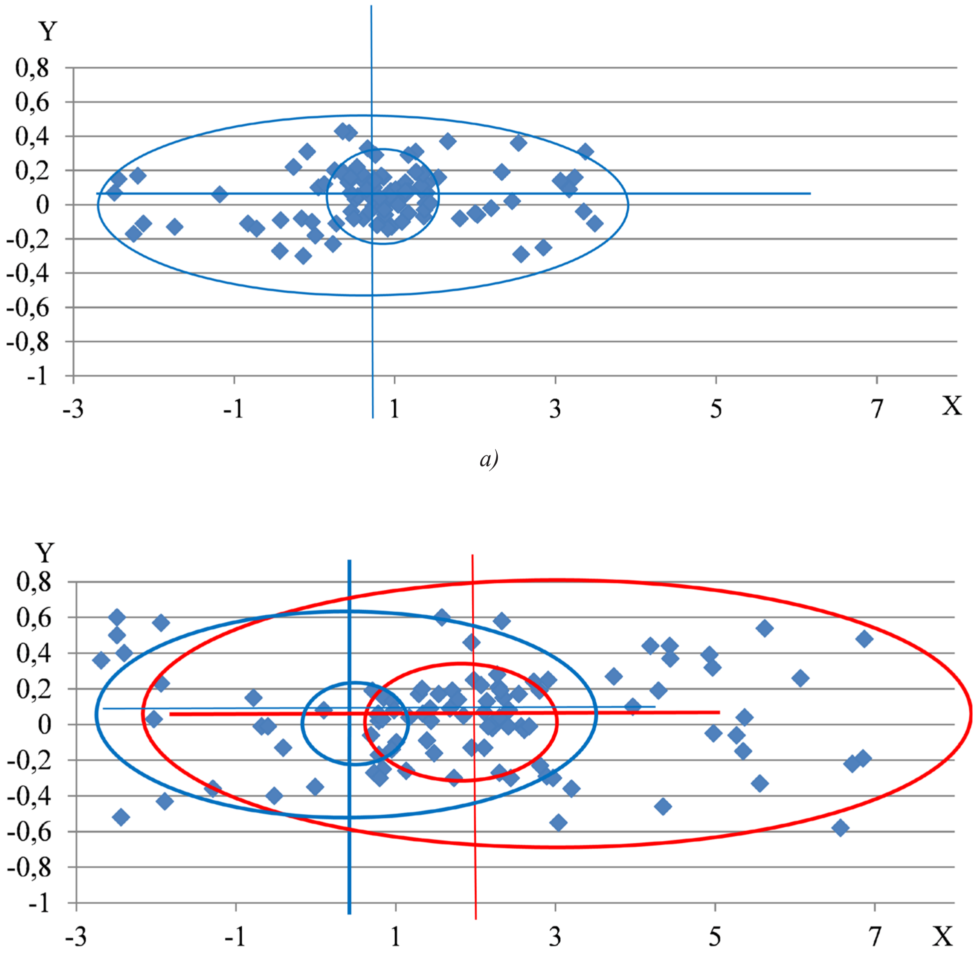
The identification of a person's emotional state in real time is based on the variance analysis of the models of spontaneous (optimal), emotional and reasonable activities:

- variance analysis with respect to a point;
- variance analysis provided that each point is treated as a random vector with a start at the beginning of the coordinates and an end at a specific point;
- variance analysis in relation to the area in the form of a square, inside which there are points corresponding to the person's emotional state.

Table 1 shows the variance calculation of the deformity from the spontaneous (optimal) type to the reasonable type of the person's activity, and Figure 3 shows its graphical representation. The deformity of the emotional state is determined using a priori person's models based on the actual material of a posteriori research of the accident investigations.

Table 1. The calculation of the variance of deformity from the spontaneous type into a reasonable type of the person's activity

Variance calculation		Type of activity		
		Spontaneous type	Reasonable type	Difference, Δ
Distribution center of the random variable	X_0	0.70	2.04	-1.34
	Y_0	0.05	0.03	0.02
Variance	D	0.67	1.77	-1.10



a)

b)

Figure 3. Graphical presentation of the variance of deformity from the spontaneous type into a reasonable type of the person's activity: a) Spontaneous type of activity; b) Reasonable type of activity

Table 2 shows the calculation of the deformity from the spontaneous type to the reasonable type of the person's activity, and Figure 4 shows its graphical presentation.

Table 2. The calculation of the deformity from the spontaneous type into a reasonable type of the person's activity

Spontaneous type	*X*	0.26	0.87	1.38	0.87	1.22	0.46	0.73	1.20	1.31	0.95	1.16	1.28
	Y	-0.03	0.14	-0.11	0.09	0.07	0.07	0.05	0.04	0.06	0.11	0.18	-0.07
Reasonable type	*X*	2.03	1.17	2.75	2.32	2.22	2.88	2.25	2.68	0.61	2.99	0.80	2.64
	Y	-0.02	0.10	0.15	0.15	-0.08	0.03	0.09	-0.07	-0.02	-0.07	0.16	0.01

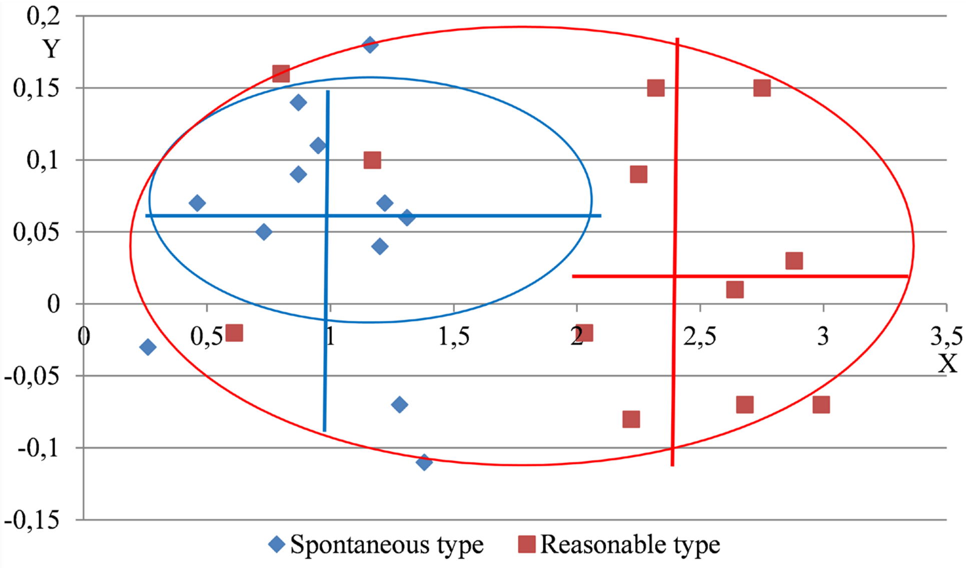


Figure 4. Graphical presentation of the deformity from the spontaneous type into a reasonable type of the person's activity

During deformity, there is a transition from one stationary emotional state of the person to another, which is a multiphase transient stationary process.

The stability of the system is determined on the basis of the analysis of the transient process or the coefficients and roots of the characteristic polynomial. In the theory of automatic control, another effective method for assessing stability is the use of stability criteria – generalized indicators that do not require solving the system equations. Algebraic and frequency criteria are used [38].

Algebraic criteria establish necessary and sufficient conditions for stability based on determinants consisting of the coefficients of the characteristic equation of the system. The English mathematician E. Rouse (1877) and the Swiss mathematician A. Hurwitz (1893) proposed a criterion in different forms, according to which the stability conditions are reduced to the fulfillment of inequalities that link the coefficients of the system equation. To solve applied problems, these criteria are combined into one - the Rausch-Gurwitz criterion. In general, these criteria were intended to solve a purely mathematical problem – the study of the stability of solutions to a linear differential equation. This equation describes the behavior of a linear system [38].

For high-order systems ($n \geq 3$), the use of the algebraic Rausch-Hurwitz criterion becomes impractical and requires cumbersome expressions. Moreover, this criterion cannot be used to determine what measures should be taken to ensure stability. The theory of automatic control also uses the algebraic Lienard-Shippar criterion (1914), which simplifies the use of the Rausch-Hurwitz criterion.

One of the frequency criteria was proposed in 1932 by the American physicist H. Nyquist, who studied the properties of electronic amplifiers with feedback. This criterion later became one of the most widely used in studies on the stability of automatic systems [38].

Unlike other criteria based on the analysis of the system's characteristic equation, the Nyquist criterion uses the amplitude-phase characteristic of an open-loop system $W_{open}(jw) = W(jw)_o\ W(jw)CO$, i.e., the serial connection (product) of the respective characteristics and transfer functions of the regulator and the control object via the control channel. This makes the criterion clear and easy to use, and it is possible to use the experimental dynamic characteristics of the object. This criterion is especially convenient for single-circuit systems, which can be represented as typical connections. The main application of the Nyquist criterion relates to systems that are stable in the open state, which in most cases is the case for technical objects. In this case, the Nyquist criterion is formulated as follows: a control system is stable if the amplitude-phase response of the open-loop system *W(jw)* does not cover the point with coordinates (-1; *j*0).

Nyquist criterion is convenient to use for analyzing systems that have delayed links in their structure (operators). In this case, the amplitude-phase characteristic of an open-loop system can be represented as a formula:

$$W_{open}(jw) = W(jw)_{basic}\, e^{-jw\tau} \tag{1}$$

where $W(jw)_{basic}$ – are the amplitude-phase characteristics of the basic elements of the system;

$e^{-jw\tau}$ – are the amplitude-phase characteristic of the delay links.

The presence of a delayed link, as a rule, worsens the stability and there is a critical delay at which the system reaches the limit of stability w_{kr}.

For example, the transfer function of the open-loop human-machine system "Air Traffic Controller – Pilot – Aircraft (ACFT)" is determined by the formulas:

$$W_{open}(p) = W_o(p) W_{ACFT}(p) W_D(p) = \frac{K_o K_{ACFT} K_D e^{-\tau p}}{(T_o p+1)(T_{ACFT} p+1)p}; \tag{2}$$

$$W_{open}(p) = \frac{2\cdot 2{,}5K_D}{(0{,}125p+1)(1{,}8p+1)p} e^{-0{,}15p} = \frac{5K_D}{0{,}225p^3+1{,}925p^2+p} e^{-0{,}15p}, \tag{3}$$

where K_o, K_{ACFT}, K_D – are the amplification coefficients of the operator, aircraft, and models of the person's activity: $K_o = 2$; $K_{ACFT} = 2{,}5$ sec^{-1}; $K_D = f(D) = var$;

T_o, T_{ACFT} – are the delay times of the operator and aircraft: $T_o = 0{,}125$ sec.; $T_{ACFT} = 1{,}8$ sec;

τ – is the time of the operator's neuromuscular delay: $\tau = 0{,}15$ sec.

The frequency transfer function (without taking into account the delay in the system):

$$W_{open}(jw) = \frac{5K_D}{0{,}225(jw)^3+1{,}925(jw)^2+jw} = \frac{5K_D}{-0{,}225jw^3-1{,}925jw^2+jw} = \frac{5K_D}{-1{,}925w^2+j(w-0{,}225w^3)}; \tag{4}$$

$$\begin{aligned} W_{open}(jw) &= \frac{5\cdot(-1{,}925w^2 - j(w-0{,}225w^3))K_D}{-1{,}925^2w^4+(w-0{,}225w^3)^2} = \frac{-5\cdot 1{,}925w^2 - 5jw + 5\cdot j\cdot 0{,}225w^3}{-1{,}925^2w^4+w^4-2\cdot 0{,}225w^4+0{,}225^2w^6}K_D = \\ &= \frac{-9{,}625w^2-5jw+1{,}225jw^3}{0{,}225^2w^4+w^4+3{,}25w^4+w^2}K_D = \frac{-9{,}625w^2}{0{,}05w^6+3{,}25w^4+w^2}K_D + j\frac{1{,}225w^3-5w}{0{,}05w^6+3{,}25w^4+w^2}K_D = \\ &= U(w)+jV(w), \end{aligned} \tag{5}$$

where *U(w)* – is a real part;

V(w) – is an imaginary part.

The person's functional stability is measured using the Nyquist criterion. In spontaneous (optimal) control, the Nyquist hodograph does not contain the critical point (-1; *j*0) and the human-machine system is stable.

The Nyquist hodograph by the type of psychic activity for diagnosing the emotional state of the person and determining the stability of a human-machine system during the deformity of emotional experience is built (Figure 5): spontaneous $K_D(D_1)$=0,67; reasonable $K_D(D_3)$=1,77; emotional $K_D(D_2)$=3,19.

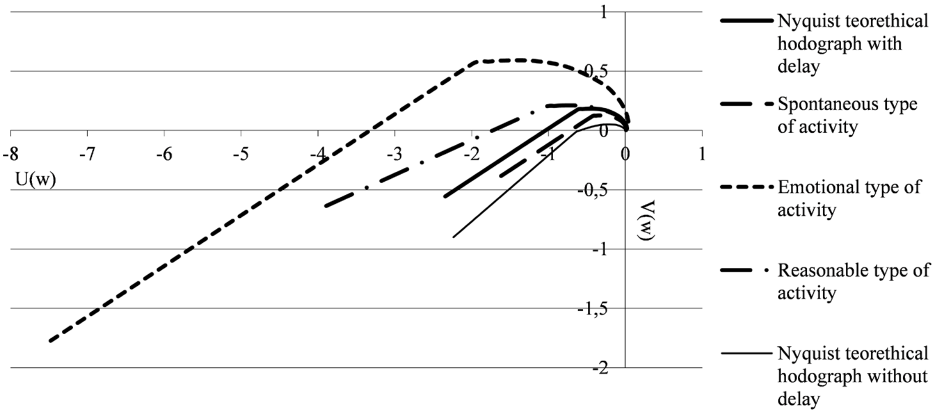


Figure 5. Nyquist hodograph for diagnosing the person's emotional state and determining the human-machine system stability during the deformity of emotional experiences

Method of real-time diagnosis of the person's emotional state:

1. Identification of an emotional portrait of a *j*-person based on models for spontaneous, emotional and reasonable

types of the person's activity obtained by a phase trajectory of the monitored value deflection ($F_i=f(D_{ij})$).

2. Identification of the emotional state of a *j*-person, comparison of his portrait and emotional boundaries with appropriate variations ($F_{min}=f(D_{min})$, $F_i=f(D_{ij})$, $F_{max}=f(D_{max})$) and the type of emotional activity of the person: $F_{min}=f(D_{min}) < F_i=f(D_{ij}) < F_{max}=f(D_{max})$.

3. Diagnosis of the deformity of emotional experience (state) as transitions to hazardous activities of the person (rational or emotional): $F_i=f(D_{ij}) > F_{max}=f(D_{max})$, $F_i=f(D_{ij}) < F_{max}=f(D_{max})$.

4. Determination of the type of operational activity in psychic deformity of the emotional state using models to identify spontaneous, emotional and reasonable types of the person’s activity and determination of the corresponding variances: $Di>Dmax$, $Di<Dmin$.

5. Determination of the stability of a human-machine system by the Nyquist criterion concerning variances based on an operational model of emotional state.

6. Indication of the results of diagnostics of the person’s emotional state using an active panel for displaying digital data encoding.

A software “Diagnostics of the emotional state of a human-operator” was developed for the information-analytical diagnostic complex for assessing the psychophysiological properties of a human-operator to study the activity patterns of the aviation specialists [37]. The diagnostic module is designed to quickly identify deformity in the operator's emotional experience and prevent him from making decisions in extreme situations.

Medical Intelligent Remote Monitoring System of the person’s emotional state

The problem of effective monitoring and diagnosis of a person's emotional state can be solved with the help of an Intelligent Remote Monitoring System (IRMS) [39]. It is proposed to consider a person (P) as a control object (CO). The monitoring and diagnosis of the emotional state is based on the analysis of the phase portrait obtained by the control device (CD) (Figure 6).

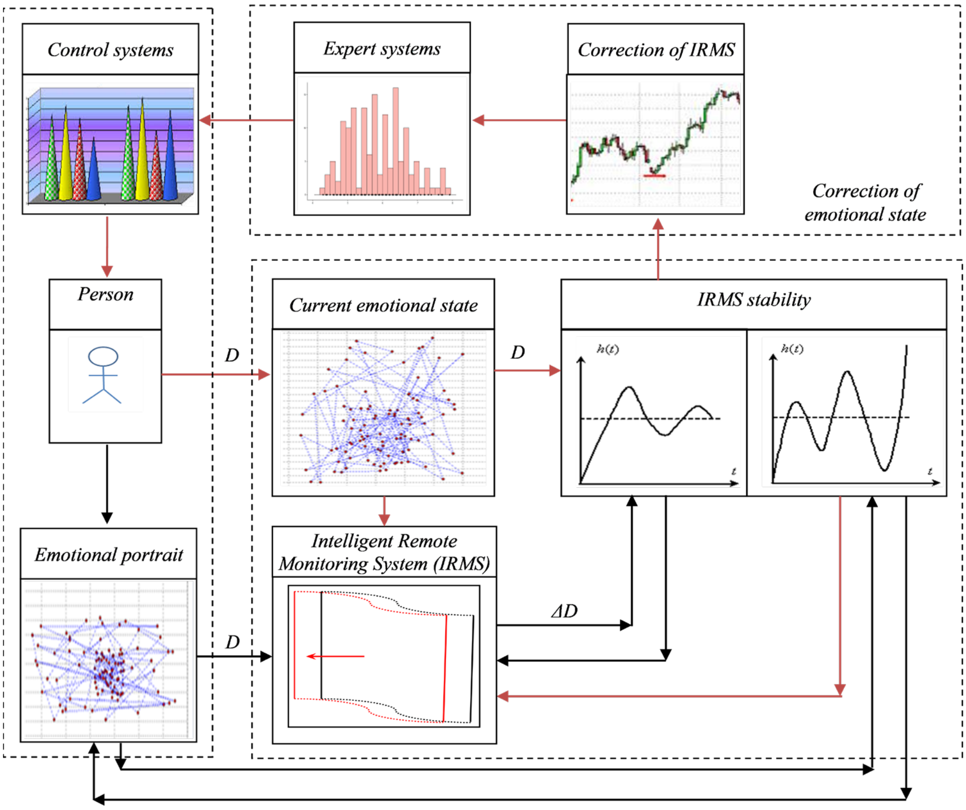


Figure 6. The conceptual model of medical IRMS

The algorithm for monitoring and diagnosing a person’s emotional state:

1. Definition of a phase portrait of person P_n – diagnosis of the normal emotional state based on the productivity, motion and communications features, etc.

2. Implementation of person parameters into the IRMS contour and real-time monitoring of the person's emotional state P_n.

3. Analysis of IRMS “CD – P_n” (person’s emotional state in real time):

a) defining IRMS “CD – P_n” stability (Mikhailov and Nyquist criteria);

b) defining the area of IRMS “CD – P_n” stability;

c) system correction in case of violation of IRMS “CD – P_n” stability;

d) defining the characteristics of links to correct the person's emotional state.

4. Synthesis of a new corrected IRMS "CD – P_{n+1}".

5. Analysis of a new upgraded IRMS "CD – P_{n+1}" (person's emotional state in real time).

To test a unified systematic approach to the study of polyergic systems, it is advisable to reduce the whole variety of control systems to several typical systems, in which the functioning of main elements should be evaluated during the study of any system identification.

The application of dynamic modeling to solve the problems of maintaining complex technical ergatic systems can lead to such models. The approach is to build a system of equations that describes the CO and P equations of the automatic control system, analyze the control system for stability, and synthesize a new reliable system.

RMS "CD – P" can be displayed by following the functional diagram (Figure 7), which reflects the person's activity in monitoring his emotional state, i.e. during changes in arterial pressure – Ψ_a.

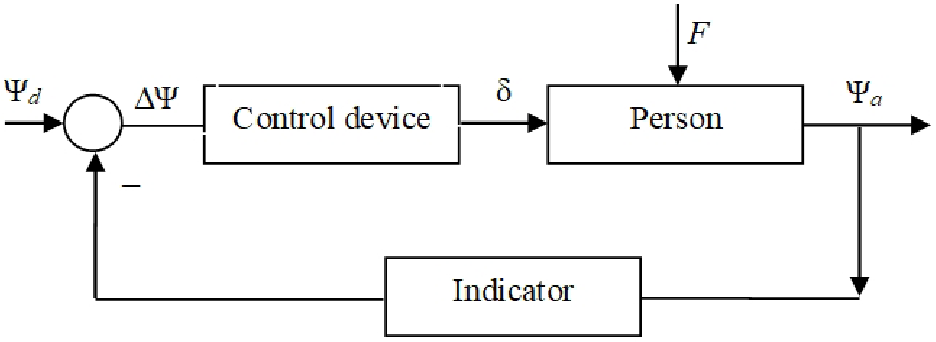


Figure 7. Functional diagram of IRMS "CD – P"

In the identification with deviation indicators $\Delta\Psi$ ($\Delta\Psi = \Psi_a - \Psi_d$), the actual blood pressure Ψ_a from defined pressure Ψ_d of the person, analyzes the relevant information and monitors the defined actions δ until the deviation $\Delta\Psi$ disappears. The stability of the IRMS "CD – P_n" is obtained using the criteria of Mikhailov and Nyquist.

Defining IRMS "CD – P" stability using the Mikhailov criterion

The Mikhailov stability criterion (1936), along with the Nyquist stability criterion, is a frequency-based stability criterion, unlike algebraic criteria such as the Rausch and Hurwitz stability criteria. Mikhailov criterion is quite convenient for analyzing linear systems, especially of high order.

To find a hodograph by the Mikhailov criterion, it is necessary to substitute the resulting vector *M(jw)* into the characteristic equation *jw* instead of *p* as the sum of the real *P(w)* and the imaginary *Q(w)* parts:

$$M(p)=(T_2p+1)(T_3p+1)+K_1K_2K_3K_{ind}K_{CD}(T_1p+1); \tag{6}$$

$$M(jw)=(T_2jw+1)(T_3jw+1)+K_1K_2K_3K_{ind}K_{CD}(T_1jw+1)=P(w)+jQ(w); \tag{7}$$

$$P(w)=1+K_1K_2K_3K_{ind}K_{CD}-T_2T_3w^2; \tag{8}$$

$$Q(w)=(T_2+T_3+K_1K_2K_3K_{ind}K_{CD}T_1)w, \tag{9}$$

where *P(w)* – is a real part;

Q(w) – is an imaginary part;

T – are the delay times;

K – are the amplification coefficients.

Based on the characteristics of the values of *P(w)* and *Q(w)*, a Mikhailov hodograph is constructed (Figure 8).

The calculation of the real and imaginary parts of the vector *M(jw)* is performed using MS Excel, when the frequency parameter *w* changes from 0 to ∞. If the hodograph covers two quadrants (n=2) in the positive direction (counterclockwise), the system is stable (Figure 8a). If we change some coefficients, namely the delay time T_3 = 1, changed to T_3 = 0.1, in Figure 8b we have T_1 = T_2= 1, and in Figure 8c we have K_{ind} = 100, K_{CD} = 100. Thus, as the control coefficients increase, the stability areas increase.

Defining IRMS "CD – P" stability using the Nyquist criterion

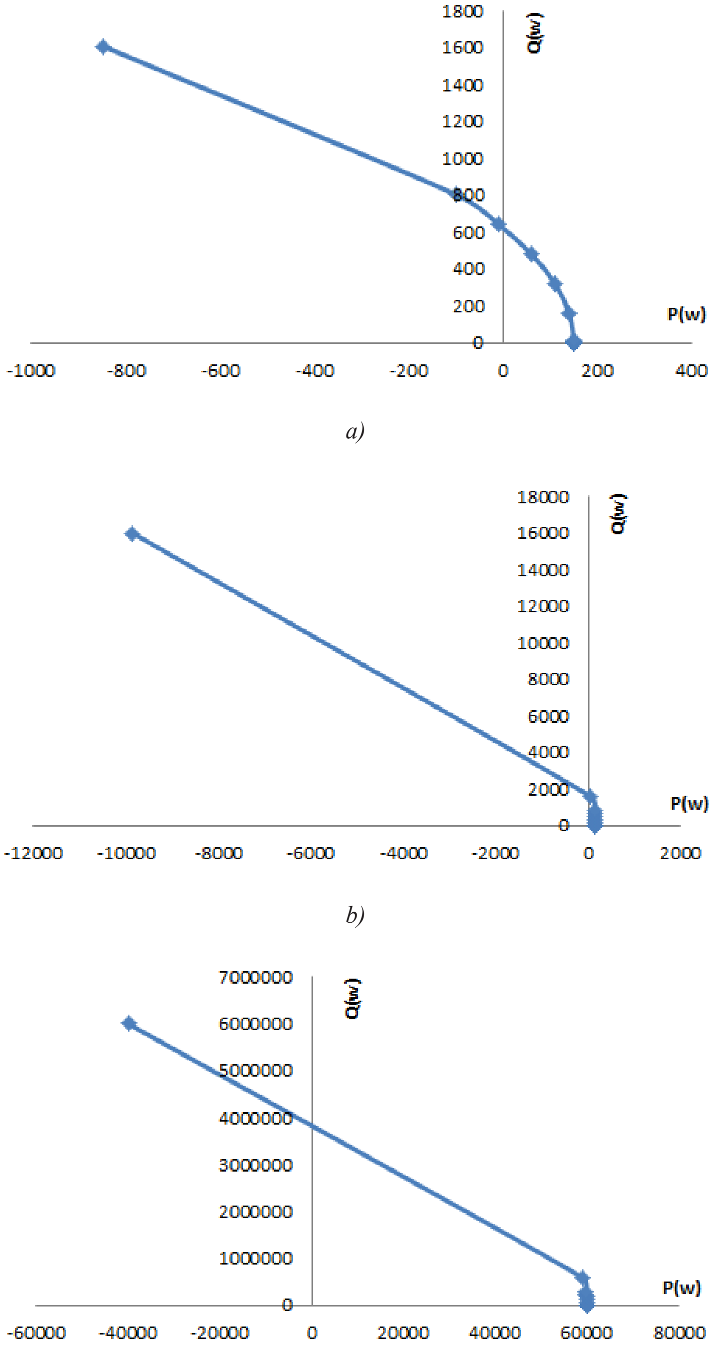
The system stability is determined by the Nyquist criterion with an appropriate deformity of emotional experience. For example, the stability of a nuclear power plant is determined by the Nyquist criterion, taking into account the deviations according to the operational model in the emotional state. The Nyquist hodograph without delay for IRMS is shown in Figure 9.

The Nyquist hodograph does not contain the critical point (-1; *j*0), so the system is stable.

The use of IRMS is significant in many situations:

- inpatients usually need 24-hour monitoring of the relevant internal organs (kidneys, lungs, brain, intestines, spleen, heart, etc.) for the period of recovery;

- during treatment, the patient's psycho-emotional state is of great importance, as the diagnosis and correction of the emotional state has a positive impact on the outcome of treatment.



a)

b)

c)

Figure 8. Mikhailov hodograph: a) $T_3 = 1$; b) $T_1 = T_2 = 1$; c) $K_{ind} = K_{cd} = 100$

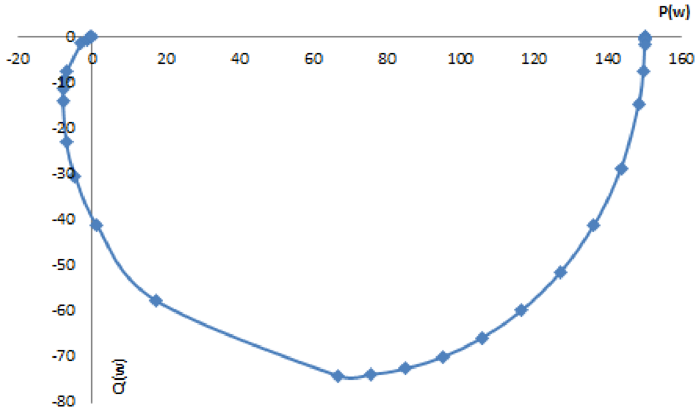


Figure 9. Nyquist hodograph for monitoring the person's emotional state in IRMS

Illustrative examples

Non-stochastic collaborative decision-making models (CDM) during urgent medical cargo delivery using UAV

CDM is an efficient process of data exchange and personal and joint decision-making by the various participants. The identification of potential participants in the delivery process of medical cargo depends on the purpose of the mission, the characteristics of the medical cargo, the urgency of delivery, the delivery distance, etc. As a rule, the participants in the delivery process are the sender and the recipient (medical personnel) and delivery specialists (logistics/transportation company). It is important to ensure that the CDM with the partners is possible at a reasonable level of efficiency and balance (minimum risk and maximum safety).

As an example, consider the problem of an urgent medical cargo delivery using an Unmanned Aerial Vehicle (UAV) from points *A*, *B* and *C* to problem point *D* (Figure 10).

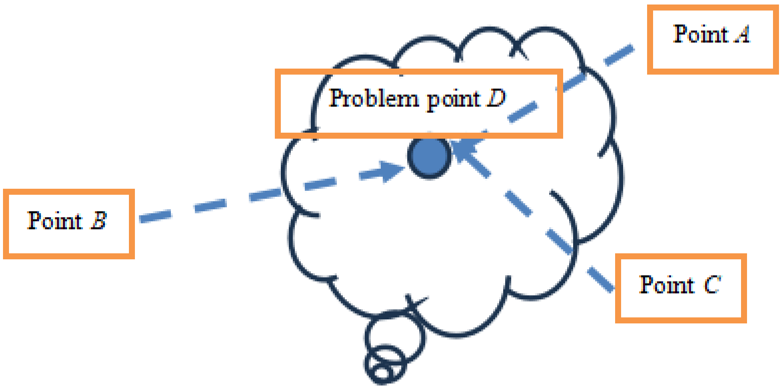


Figure 10. Example of the problem of an urgent medical cargo delivery using UAV from points *A*, *B* and *C* to problem point *D*

Methods of CDM [40, 41]:

1. Method for integrating decision-making models in certainty, risk and uncertainty (deterministic and stochastic models).
2. Method of subjective-objective CDM based on individual and collaborative decision-making models.
3. Method for managing the development of the situation by using the integration of decision-making models (non-stochastic, stochastic and deterministic models) and CDM models (individual and collaborative decision-making models).
4. Method of CDM modeling based on the priority of the factors influencing decision-making.
5. Method of CDM modeling based on the priority of the Hurvitz criteria.

The application of the objective-subjective CDM method in uncertainty for the formation of joint decision:

1. Forming the alternative decisions *{A}* and the analysis of the alternative decisions (Figure 11) if the problem point is Khust:

- A_1 – Mukachevo;
- A_2 – Mizhhir'ya;
- A_3 – Rakhiv.

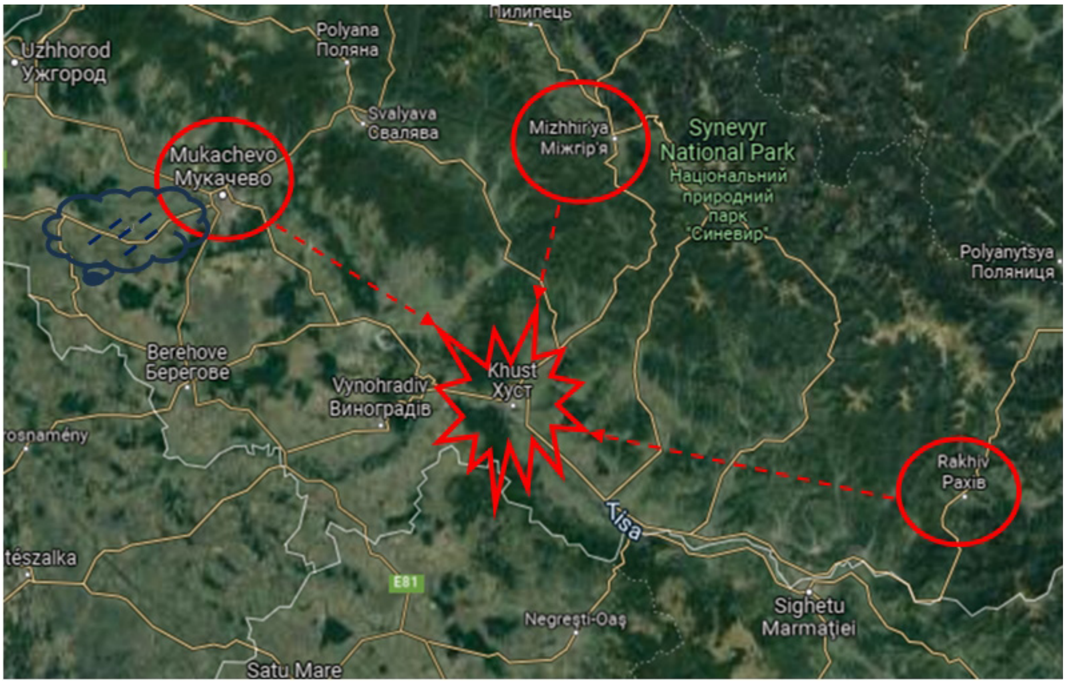


Figure 11. The fragment of the geographical map

2. Selection of the main factors affecting the decision-making *{F}*:

- f_1 – distance, time of flight;
- f_2 – technical characteristics of the UAV, fuel amount;
- f_3 – meteorological conditions;
- f_4 – navigation aids.

3. Forming the individual decision-making matrices in uncertainty for each participant with possible results of choice *{U}* (Table 3). The possible results of the choice *{U}* are determined by statistical data (if possible) or by the Expert Judgment Method (EJM) based on the data of the regulatory documents and the opinions of the participants.

Table 3. Individual decision-making matrix in uncertainty for each participant

	{A}	**Objective factors F_1**						**Results by criteria**			
		f_1	f_2	…	f_j	…	f_n	**Wald**	**Laplace**	**Hurwitz**	**Savage**
Alternative solutions	A_1	U_{11}	U_{12}	…	U_{1j}	…	U_{1n}	F_{11}	F_{11}	F_1	F_{11}
	A_2	U_{21}	U_{22}	…	U_{2j}	…	U_{2n}	F_{21}	F_{21}	F_2	F_{21}
	…	…	…	…	…	…	….				
	A_i	U_{i1}	U_{i2}	…	U_{ij}	…	U_{in}	F_{i1}	F_{i1}	F_{i1}	F_{i1}
	…	…	…	…	…	…	…				
	A_m	U_{m1}	U_{m2}	…	U_{mj}	…	U_{mn}	F_{m1}	F_{m1}	F_{m1}	F_{m1}

The optimal solution is sought using the criteria of Wald, Laplace, Hurwitz and Savage – with minimum loss and maximum safety during the transportation. Each of the criteria has respective differences in their applicability. The primary difference lies in the varying degrees of uncertainty of the problem, types of situations (frequent, infrequent, first-time), transportation capabilities and severity of the relief situation. For example, the Laplace criterion is built on more optimistic views (the same situations as they were); the Wald criterion is built on more pessimistic views and is used to find the best solution at the initial moment. The ratio of optimism and pessimism is used in the Hurwitz criterion, which can be tailored with different approaches from the most optimistic to the most pessimistic estimation. The Savage criterion is used to recalculate the solutions to minimize losses after the situation is over:

- the Wald criterion (maxmin):

$$A^* = \max_{X_i} \left\{ \min_{Y_j} U_{ij}(X_i, Y_j) \right\}, \tag{10}$$

where X_i – is an alternative solution from the set *{A}*;
Y_j – is a factor from the factors' set *{F}*;

- the Laplace criterion:

$$A^* = \max_{X_i}\left\{\frac{1}{n}\sum_{j=1}^{n}U_{ij}(X_i,Y_j)\right\}, \tag{11}$$

where n – is a number of factors that affect;

- the Hurwicz criterion:

$$A^* = \max_{X_i}\left\{\alpha \max_{Y_j}U_{ij}(X_i,Y_j)+(1-\alpha)\min_{Y_j}U_{ij}(X_i,Y_j)\right\}, \tag{12}$$

where α – is an optimism-pessimism coefficient, $0 \le \alpha \le 1$, 0 – is the marginal of pessimism, and 1 – is the marginal of optimism;

- the Savage criterion:

$$A^* = \min_{Y_j}\max_{X_i} R_{ij}(X_i,Y_j), \tag{13}$$

where R_{ij} – is a loss matrix for recalculations after making an individual decision with maximum safety:

$$R_{ij}(X_i,Y_j) = \underset{X_i}{\Delta} = \max_{Y_j}U_{ij}(X_i,Y_j) - U_{ij}(X_i,Y_j). \tag{14}$$

4. Forming the CDM matrix under uncertainty for all participants involved in a decision making *{P}* (CDM team) (Table 5):

- P_1 – remote pilot;
- P_2 – air traffic controller;
- P_3 – medical personnel (telemedics);
- P_4 – logistics/transportation company.

In Table 4, factors are the participants' opinions on UAV transportation, and alternative solutions are the common possible actions. The optimal solution is with minimal losses and maximum safety during the transportation, considering all participants' opinions.

Table 4. CDM matrix in uncertainty for all participants

	{A}	**Subjective factors F_2**						**Results by criteria**			
		f_1	f_2	…	f_j	…	f_n	**Wald**	**Laplace**	**Hurwitz**	**Savage**
Alternative solutions	A_1	F_{11}	F_{12}	…	F_{1j}	…	F_{1n}	AS_1	AS_1	AS_1	AS_1
	A_2	F_{21}	F_{22}	…	F_{2j}	…	F_{2n}	AS_2	AS_2	AS_2	AS_2
	…			…		…					
	A_i	F_{i1}	F_{i2}	…	F_{ij}	…	F_{in}	AS_i	AS_i	AS_i	AS_i
	…			…		…					
	A_m	F_{m1}	F_{m2}	…	F_{mj}	…	F_{mn}	AS_m	AS_m	AS_m	AS_m

Possible results considered by each participant with different optimism-pessimism coefficients following the Hurwitz criterion (method of CDM modeling based on the priority of the Hurvitz criteria) are represented in Tables 5-8. The example of assessing the factors that influence the decision making by the remote pilot (participant P_1) is shown in Figure 12.

Table 5. Individual decision-making matrix in uncertainty for the remote pilot (participant P_1)

	{A}	**Objective factors F_1**				**Results by criteria**		
		f_1	f_2	f_3	f_4	**Wald**	**Laplace**	**Hurwitz, α = 0.5**
Alternative solutions	A_1	0.9	0.9	0.3	0.7	0.3	***0.7***	0.6
	A_2	0.6	0.7	0.6	0.8	***0.6***	***0.7***	***0.7***
	A_3	0.5	0.7	0.7	0.6	0.5	0.6	0.6

Table 6. Individual decision-making matrix in uncertainty for the air traffic controller (participant P_2)

Alternative solutions	{A}	Objective factors F_1				Results by criteria		
		f_1	f_2	f_3	f_4	Wald	Laplace	Hurwitz, α = 0.5
	A_1	0.9	0.9	0.3	0.7	0.3	***0.7***	0.5
	A_2	0.6	0.7	0.4	0.8	0.4	0.6	0.5
	A_3	0.5	0.7	0.5	0.7	***0.5***	0.6	***0.6***

Table 7. Individual decision-making matrix in uncertainty for the medical personnel (participant P_3)

Alternative solutions	{A}	Objective factors F_1				Results by criteria		
		f_1	f_2	f_3	f_4	Wald	Laplace	Hurwitz, α = 0.3
	A_1	0.4	0.9	0.3	0.7	0.3	0.6	0.4
	A_2	0.6	0.7	0.6	0.8	***0.6***	***0.7***	***0.7***
	A_3	0.5	0.7	0.7	0.6	0.5	0.6	0.6

Table 8. Individual decision-making matrix in uncertainty for the logistics/transportation company (participant P_4)

Alternative solutions	{A}	Objective factors F_1				Results by criteria		
		f_1	f_2	f_3	f_4	Wald	Laplace	Hurwitz, α = 0.2
	A_1	0.9	0.7	0.5	0.7	0.5	***0.7***	***0.8***
	A_2	0.6	0.7	0.6	0.8	0.6	***0.7***	***0.8***
	A_3	0.7	0.7	0.7	0.7	***0.7***	***0.7***	0.7

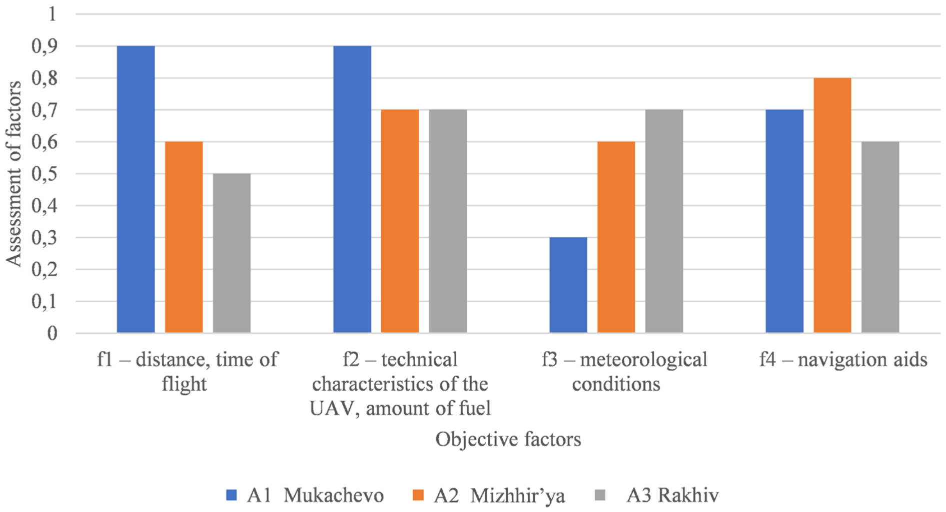


Figure 12. Assessment of the factors influencing decision-making by the remote pilot (participant P_1)

The optimal decisions by the criteria of Wald, Laplace and Hurwitz according to each participant are:

- for the remote pilot (P_1): by the Wald, Laplace and Hurwitz criteria – A_2 (Mizhhir'ya); by the Laplace criterion – A_1 (Mukachevo);

- for the air traffic controller (P_2): by the Wald and Hurwitz criteria – A_3 (Rakhiv); by the Laplace criterion – A_1 (Mukachevo);

- for medical personnel (P_3): by the Wald, Laplace and Hurwitz criteria – A_2 (Mizhhir'ya);

- for logistics/transportation company (P_4): by the Wald criterion – A_3 (Rakhiv); by the Laplace criterion – A_1 (Mukachevo), A_2 (Mizhhir'ya) and A_3 (Rakhiv); by the Hurwitz criterion – A_1 (Mukachevo) and A_2 (Mizhhir'ya).

CDM matrix in uncertainty for all participants with optimism-pessimism coefficients following the Hurwitz criterion α = 0,8 is shown in Table 9. The assessment of the factors influencing CDM by all participants is presented in Figure 13 and the results of CDM by the criteria of Wald-Wald, Wald-Laplace and Wald-Hurwitz are shown in Figure 14.

Table 9. CDM matrix in uncertainty for all participants by the criteria of Wald-Wald, Wald-Laplace and Wald-Hurwitz

Alternative solutions	*{A}*	Subjective factors F_2				Results by criteria		
		f_1	f_2	f_3	f_4	**Wald**	**Laplace**	**Hurwitz, α = 0.8**
	A_1	0.3	0.3	0.3	0.5	0.3	0.4	0.4
	A_2	0.6	0.4	0.6	0.6	0.4	***0.6***	0.5
	A_3	0.5	0.5	0.5	0.7	***0.5***	***0.6***	***0.6***

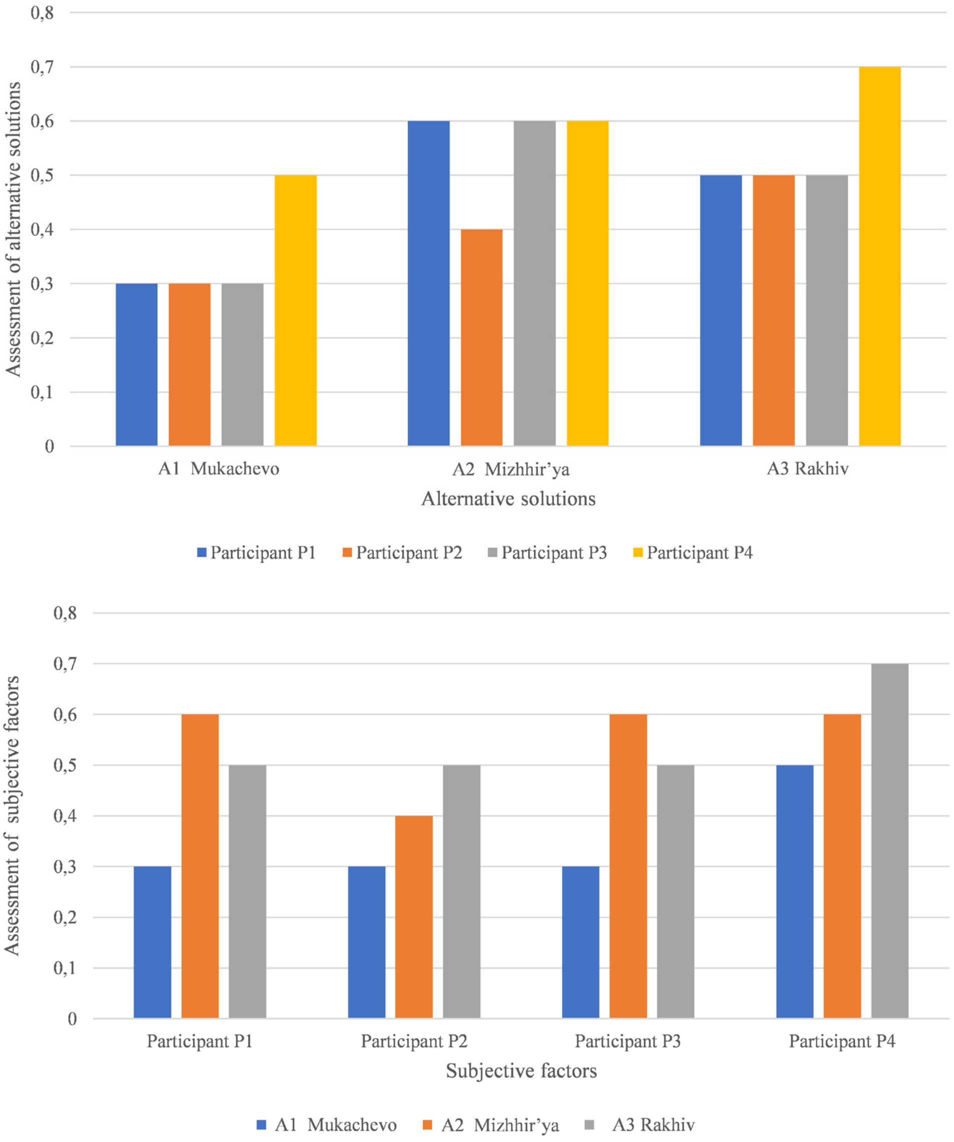


Figure 13. Assessment of the factors influencing CDM by all participants

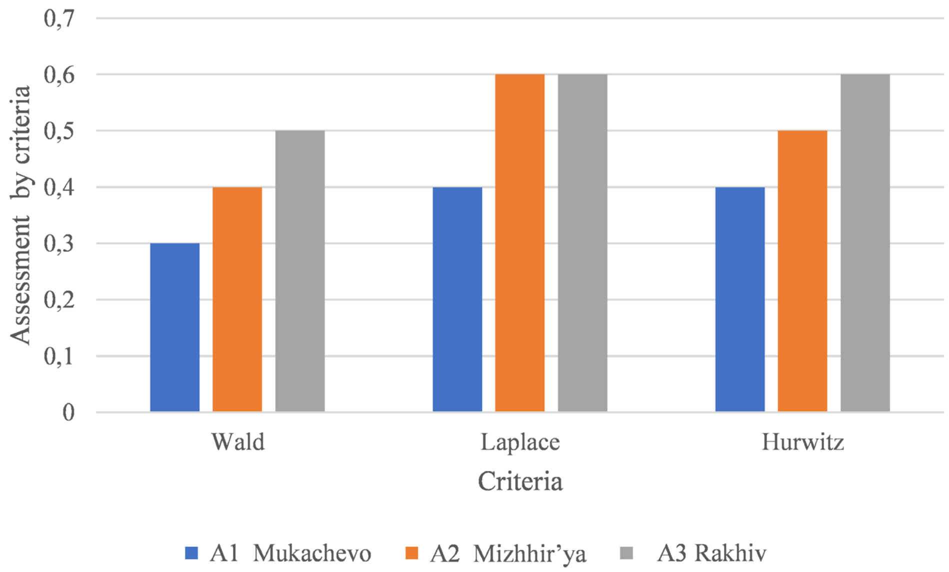


Figure 14. The results of CDM by the criteria of Wald-Wald, Wald-Laplace and Wald-Hurwitz

According to all participants' opinions, the optimal decision with minimum risk and maximum safety by the criteria of Wald-Wald, Wald-Laplace and Wald-Hurwitz during an urgent medical cargo delivery using UAV is A_3 (Rakhiv).

Finding a route of minimum cost during an urgent medical cargo delivery using UAV

Another relevant task is to find a route of minimum cost from points *A*, *B*, and *C* to problem point *D* in the *S* area, if it is necessary to urgently deliver medicines to a seriously ill patient using UAV [42, 43]. To do this, it is advisable to use the dynamic programming method.

The example of assessing and finding a route with the minimum cost R_1 for UAV$_1$ is shown in Figure 15, R_1 is equal to 39 conventional units for a fragment of the territory in Figure 16.

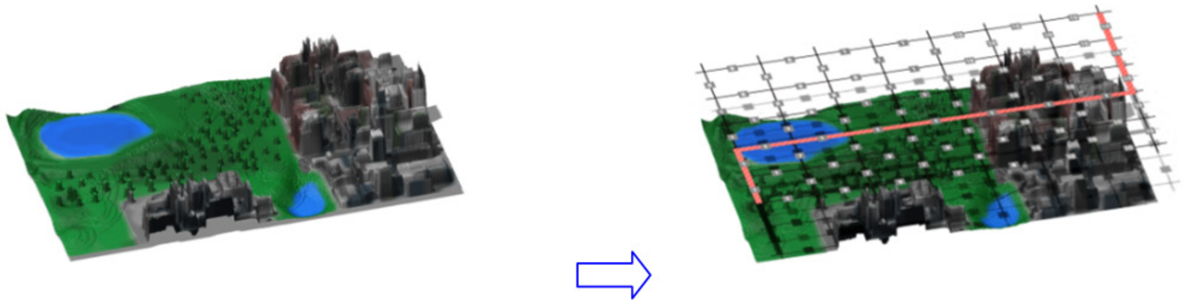


Figure 15. A fragment of the territory for assessing the minimum cost and maximum safety of UAV traffic

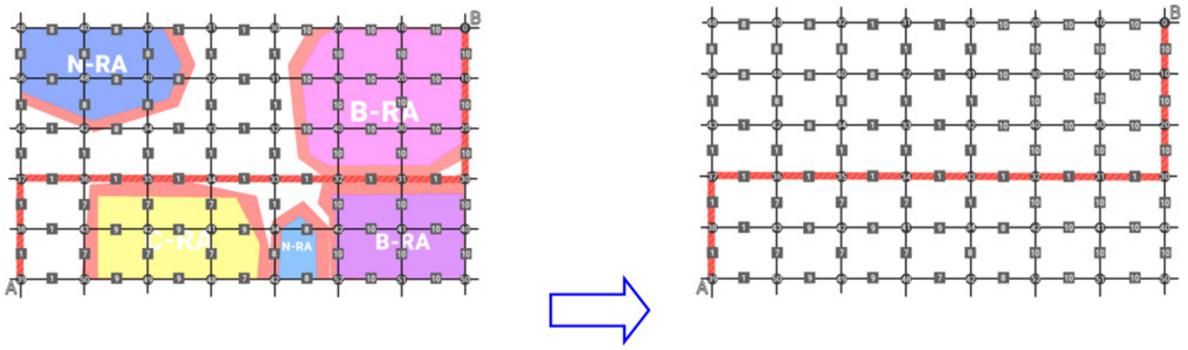


Figure 16. Assessing the risk of a grid cell and calculating the minimum cost of a route R_1 for UAV$_1$: RA – Restricted Area

For example, there is an urgent need to deliver medicines from the starting point (Uzhhorod) to the destination point (Khust). The distance between the cities of Uzhhorod and Khust is about 100 kilometers covering the area of mountainous topography, and the UAV delivers the urgent cargo at minimal cost before the medical personnel arrives (Figure 11).

The algorithm for determining the minimum cost and maximum safety of the UAV routes between the points is shown below:

1) Grid analysis – cells are overlaid on a map fragment.

2) Assessment of grid cell risks depending on the area type (Transit Area (TA), Dangerous Area (DA) or Restricted Area (RA)).

3) Finding the UAV route of the minimum cost based on the dynamic programming method for flight planning at the first level:

$$W_i(z_i)=z_{i-1}(TA;DA;RA)+\min(z_i(TA;DA;RA)). \tag{15}$$

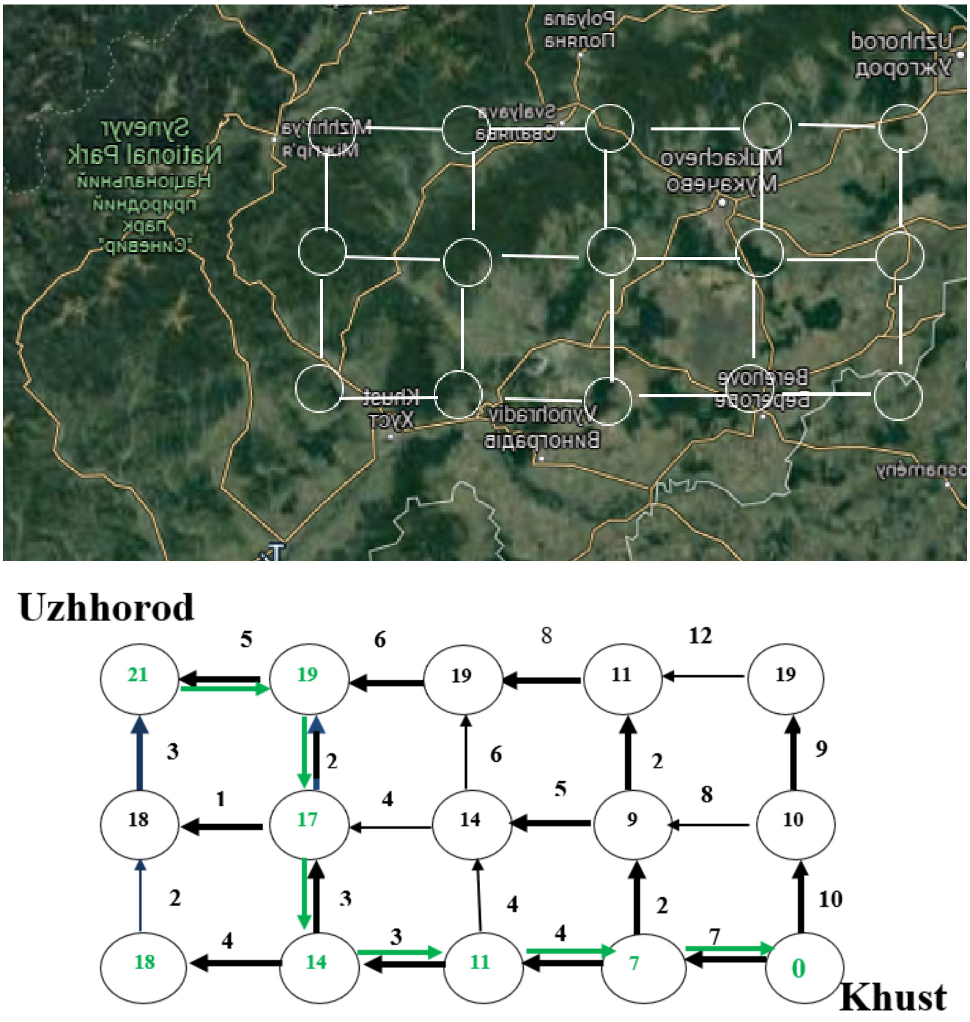


Figure 17. UAV route with the minimum cost

The minimum cost of UAV route is equal to 24 conventional units (Figure 17).

In the case of big and complex data, the method can be implemented in traditional and hybrid systems of the next generation to make decisions by handling unsupervised situation data in deep landscape models (Figure 18), potentially at a high data rate and in a close-to-real-time mode to create a structured visualization of input data in the form of clusters that match to the types of widespread situations [44-47].

In Figure 18, a deterministic action model is focused on a specific type of situation. Another benefit of this model is its capacity for learning to identify the relationships between different types of situations, almost entirely in self-learning modes with very limited requirements for reliable data. The possible applications of these capabilities of machinery intelligence models could extend, for example, to develop the ability to detect early signs or symptoms of extreme situations through the correlations between the types of situations, as well as the ability to create messages and early warnings that persons can take in anticipation for the situation developing.

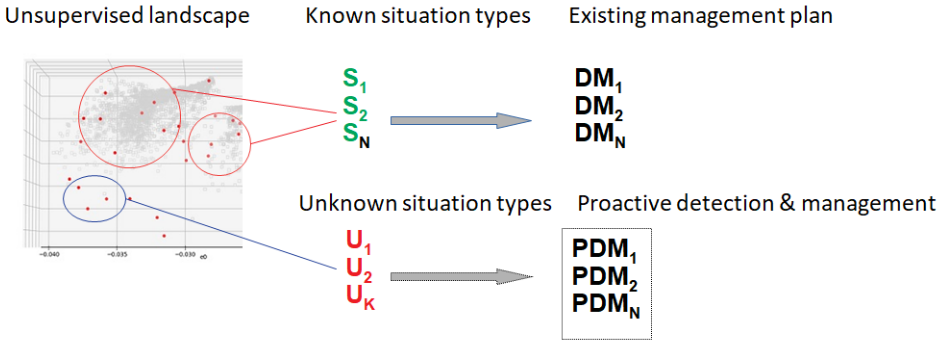


Figure 18. A prototype of a hybrid monitoring and situation management system

Results and discussion

The monitoring and diagnosis of the person's emotional state in real time is proposed to apply the concept of psychic activity, which is based on the property of the mind to slow down or speed up the flow of subjective time in relation to the real one. This is reflected in the deformity of emotional experience in the form of a transition from optimal (spontaneous) to hazardous (rational or emotional) types of human activity in extreme situations and a violation of a person's functional stability.

The phase plane method is used to timely detect a hazardous emotional state of a person in an extreme situation, the essence of which is to construct phase trajectories for differential equations in the coordinate system. Real-time identification of a person's emotional state is based on the variance analysis of the models of spontaneous (optimal), emotional and reasonable types of activity. The deformity of the emotional state is determined using a priori person's models based on the actual material of a posteriori research on the accident investigations. Nyquist hodograph for the spontaneous (optimal) type of activity is built and it does not contain the critical point (-1; *j*0) that indicates the stability of the human-machine system.

For effective monitoring and diagnosis of the person's emotional state, IRMS is built based on the dynamic modeling principles. The subsystems of IRMS are formalized in the form of transmission functions, a person is considered as a control object, and the monitoring and diagnosis of the emotional state based on the analysis of the phase portrait of control device are obtained. An example of IRMS modeling by analyzing the influence of time constants and coefficients on the stability and reliability of system using Mikhailov and Nyquist criteria is presented. If the Mikhailov hodograph covers two quadrants in the positive direction (counterclockwise), the system is stable. As the control coefficients increase, the stability areas increase.

Based on the objective-subjective CDM method in the uncertainty, the problem of an urgent delivery of medical cargo using UAV from the departure points Mukachevo, Mizhhir'ya, Rakhiv to the destination point Khust is solved. The optimal decisions by the Wald, Laplace and Hurwitz criteria according to each participant are:

- for the remote pilot: by the Wald, Laplace and Hurwitz criteria – Mizhhir'ya; by the Laplace criterion – Mukachevo;
- for the air traffic controller: by the Wald and Hurwitz criteria – Rakhiv; by the Laplace criterion – Mukachevo;
- for medical personnel: by the Wald, Laplace and Hurwitz criteria – Mizhhir'ya;
- for logistics/transportation company: by the Wald criterion – Rakhiv; by the Laplace criterion – Mukachevo, Mizhhir'ya, and Rakhiv; by the Hurwitz criterion – Mukachevo and Mizhhir'ya.

The optimal decision with minimum risk and maximum safety by the Wald-Wald, Wald-Laplace and Wald-Hurwitz criteria according to all participants' opinions on UAV transportation is found.

Based on the dynamic programming method, if it is necessary to urgently deliver medicines to a seriously ill patient, the task of finding a route of minimum cost from the starting point (Uzhhorod) to the destination point (Khust) using UAV is decided. The minimum cost of UAV route is 24 conventional units. In the case of big and complex data, the method can be implemented in traditional and hybrid systems of the next generation to make decisions by handling unsupervised situation data in deep landscape models.

Conclusions

Monitoring and diagnosis of emotional state is important for varied professional groups of persons, especially those involve in hazardous work, risks and high responsibility (pilots, astronauts, miners, sailors, firefighters, military personnel, law enforcement officers, etc.). These professions are definitely extreme. Moreover, the number of such professions and people engaged in them is constantly increasing. Unfortunately, disorders of the emotional state is not easily recognized by visible symptoms, so prompt remote diagnosis and monitoring of a person's emotional state is important, especially in conditions of complex geography, lack of transportation and mobility of patients, reduced financial resources, or lack of medical staff. In many cases, effective supports from various participants involved in a difficult situation that could become hazardous is required to make a timely decision.

For remote monitoring and diagnosis of the emotional state, the most acceptable indicators are tremor, kinematics (reproduction of a specific range of motion), reflexometry (measurement of sensorimotor reaction times), voice, facial expressions, iris changes, perspiration, finger skin temperature, blood pressure, heart rate and skin conductance. The most well-known diagnostic tools for the assessment of emotional state are Kirlian bioelectrography, ROFES functional and emotional state assessment recorder, fitness trackers and smartwatches.

The authors, who have aviation experience in operational detection of deviations in the pilot's emotional state and decision making under risk, propose to apply for the concept of psychic activity, which is based on the property of the mind to slow down or speed up the flow of subjective time in relation to the real one for monitoring and diagnosis of the person's emotional state. The phase plane method is used for operational detection of a hazardous emotional state of a person in extreme situations. The real-time identification of a person's emotional state is based on the variance analysis of the models of spontaneous (optimal), emotional, and reasonable types of activity. The deformity of the emotional state is determined using a priori person's models based on the actual material of a posteriori research on the accident investigations. For measuring the person's functional stability, the Nyquist criterion is used. The method of real-time diagnosis of the person's emotional state is presented. A software "Diagnostics of the emotional state of a human-operator" is developed.

The problem of effective monitoring and diagnosis of the person's emotional state can be solved with the help of IRMS, which is built based on dynamic modeling principles. The conceptual model and the functional diagram of medical IRMS are worked out. The algorithm of the person's emotional state monitoring and diagnosis is presented. Using Mikhailov and Nyquist criteria, the stability of IRMS is obtained and Mikhailov and Nyquist hodographs are built.

IRMS is proposed for monitoring the emotional state of the person in medicine, sports, treatment and automated monitoring of persons in hazardous environments, for example, in an aeroplane (passengers), in a smart home (people), in medicine (clients), etc. Prompt monitoring and diagnosis will allow timely adjustment and improvement of the person's emotional state and prevent the extreme situation developing towards worsening.

Based on the objective-subjective CDM method in the uncertainty, the problem of an urgent delivery of medical cargo using UAV from the departure points to the destination point is solved. The optimal decision with minimum risk and maximum safety by the Wald-Wald, Wald-Laplace and Wald-Hurwitz criteria according to all participants' opinions in UAV transportation is found.

Based on the dynamic programming method, if it is necessary to urgently deliver medicines to a seriously ill patient, the task of finding a route of minimum cost using UAV is decided. In the case of large and complex data, the method can be implemented in traditional and hybrid next-generation decision-making systems by processing uncontrolled situation data in deep landscape models.

Further research should be aimed at determining the preconditions for the occurrence of extreme situations and preventing catastrophes. It is necessary to research the applied tasks of CDM in socio-technical systems (aviation, chemical production, nuclear energy, military industry, etc.) and to develop Intelligent Decision Support Systems for operating the highly complex control systems in emergencies based on detecting changes in the phase portraits and diagnosing the deformity of the emotional state. In particular, it will be able to timely identify the emotional exhaustion (or emotional burnout syndrome) that is characterized by constant physical, psychic and moral fatigue, insomnia, headaches, eating disorders, loss of interest in favorite activities, irritability and stress. When there is a data accumulation, it is planned to create the Intellectual Decision Support System modules with the Artificial Intelligence (AI) participation. AI participant will be a member of the CDM Participants Group.

A model for synchronizing the actions of all delivery participants – the sender and the recipient (medical personnel), and the delivery specialists (logistics/transportation company) in extreme situations can be developed using AI methods. Formalizing the actions of all CDM participants using AI will enable them to determine the optimal sequence and time of the procedure to resolve the non-standard situations. To prepare the participants for proper and efficient actions in extreme conditions, the educational procedures should simulate situations as close as possible to actual incidents.

List of abbreviations and symbols

AI – Artificial Intelligence
CDM – collaborative decision-making
CD – control device
CO – control object
DA – Dangerous Area
IRMS – Intelligent Remote Monitoring System
P – person
RA – Restricted Area
TA –Transit Area
UAV – Unmanned Aerial Vehicle

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