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ALGORITHMS FOR DATA MODELS PROCESSING FOR INTEGRAL ESTIMATION OF FLIGHT CREWS' PERSONNEL STATES

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Abstract—*The algorithm for data model processing is proposed for the estimation of the physical, psychophysiological and functional state of flight crew personnel. There are the number of information technologies that combine the complexes of devices and methods to determine the psychological and psycho-physiological characteristics of operators in the process of their professional activities in present time. The work done can be used in the development of information and diagnostic system designed for automatic collection, storage and processing of physiological and psychophysiological data for preventive medical examination services for personnel from the flight crews.*

Index Terms—Functional state of operator; operator efficiency; integral estimation; regressive model; estimation of the state of flight crews' personnel.

I. INTRODUCTION

The quality and efficiency of operator work of the system of continuous interaction, which includes personnel from the flight crews as well, depends on the organism functional state (FS). There is a need for its evaluation at various stages of activity, from professional selection to operator's specialty, and ending with a periodic estimation during professional activity process.

There are a number of information technologies that combine the complexes of devices and methods to determine the psychological and psycho-physiological characteristics of operators in the process of their professional activities in present time. In [1] there is a profound analysis of literary data concerning methods that allow us to evaluate the functional state of operators.

II. PROBLEM STATEMENT

There are a number of contemporary information technologies that combine the complexes of methods and devices to determine the physical, psychological and psycho-physiological characteristics of operators of continuous interaction systems; this is linked with the needs of professional selection and ongoing control of the functional state of operators in process of their professional activity.

According to [1], the most common methods that make it possible to investigate the functional state of operators are the methods for determining of the amount of short-term memory, velocity of information perception, the intensity of attention, the accuracy and duration of time intervals reproduction, lability of the nervous system, and etc. [2]; methods for determining the values of psychophysiological characteristics of operator, estimation of the quality of activity and reliability of the system, indicators of human body subsystem activities [3] – [5].

There are also a number of complexes [6], [7], that determine the operator functional state by means of organism electrical signals (electroencephalogram, electrocardiogram, electromyogram, electrical resistance of skin).

The work of operators who control the movements of objects has characteristic features, which are caused by the significant velocity of object movements, the critical situations sudden appearances, the significant probability of environmental parameters changing, and etc. [8]. For operators located on the object, the state of their emotional tension is quite important during their activity. In addition, they depend on such factors as acceleration, pressure changes, temperature, vibration, oscillation, noises, and etc. In addition, in some cases operators should work in special equipment and be in small closed spaces; like pilots, in particular. It is clear that such system by itself increases requirements for the state of the health and physical training of operators [9], [10].

In article [11], in order to evaluate effectively the operator's work capacity, the complex methods were proposed including following estimations:

– quality of the health, including integral estimation;

– special operator abilities at defined moment;

– ability to work in extreme environmental conditions;

– recovery after fatigue;

– hidden functional reserves;

– ability for adaptation to new conditions and high loadings, and etc.

The ***purpose*** of the work is to design an algorithm for the estimation of physical, psychophysical and functional state of flight crews' personnel.

III. PROBLEM SOLUTION

Let's describe the algorithm for determining of integral estimations based on the analysis of deviations of physiological parameters from nominal values. We have to note that proposed algorithm is one of the modifications of algorithms developed by researchers of Yu. G. Antomonov school, that are based on the regression models use for the obtaining of integral estimations [12], [13]. This is significant in the case if the studied system state is evaluated using large number of parameters.

The task of estimation of the flight crew members' state is following: for each organism subsystem the estimation of the degree of this subsystem deviation from the "norm" is made separately. Then, according to obtained estimations, the evaluation of pilot organism state have to be constructed as a whole in form of a linearly weighed sum.

Let's identify with the system S any of blocks or any subsystem. This system is characterized by indicators S. Let's suppose that the intervals of changes of real values $x_1, x_2, ..., x_n$ are known:

$$x_{i_{\min}} \le x_i \le x_{i_{\max}}. \qquad (1)$$

As well as intervals of changes x_i, when professionals consider i values in "normal" limits, or

$$x^n_{i\ \min} \le x_i \le x^n_{i\ \max}. \qquad (2)$$

It is clear that $x^n_{i_{\min}}$, $x^n_{i\ \max}$ satisfy the condition

$$x_{i_{\min}} \le x^n_{i_{\min}} < x^n_{i_{\max}} \le x_{i_{\max}}, \qquad (3)$$

we introduce for each x_i the pair of logical signs α_i, β_i, whose values (0 or 1) are given from the physiological or psychophysiological peculiarity of the indicator. Lets suppose that for $\alpha_i = 0$ is measured parameter x_i, that lies to the left of the interval "norm", or when

$$x_{i_{\min}} \le x_i \le x_{i_{\max}}. \qquad (4)$$

It does not refer to one that is deviated from the "norm" to the field of pathological values according to its physiological or psycho-physiological peculiarities. In this case, we can extend the interval "norm" for this indicator to the left, up to the value $x_{i_{\min}}$. In the opposite case, for $\alpha_i = 1$ the value x_i that satisfies (4), should be considered as one that characterizes the pathological process, or, as going beyond the limits of the "norm" to the left in the area of pathological values.

The similar appointment has a sign β_i. The difference is that sign β_i extends to the case when the measured indicator x_i satisfies the condition

$$x^n_{i_{\min}} \le x_i \le x_{i\ \max}, \qquad (5)$$

and, therefore, deviates from the given interval "norm" to the left.

Thus, for $\beta_i = 0$ interval there is no interval of pathological parameters of the parameter $(x^n_{i_{\max}}, x_{i_{\max}}]$, and, in this case, interval "norm" $[x^n_{i_{\min}}, x^n_{i\ \max}]$ we can to extend to the right up to the interval $[x_{i_{\min}}, x_{i_{\max}}]$. For $\beta_i = 1$ interval $(x^n_{i_{\max}}, x_{i_{\max}}]$ is considered for x_i as area of pathological values.

Let's also introduce for each x_i the sign p_i. When user of algorithm for index x_i states the sign $p_i = 1$, this may mean that he wants to take into account this index x_i for the estimation of physiological or psychophysiological state of system S. For $p_i = 0$ system index or has not been stated by researcher, or x_i not necessary to take into account in this task for construction of estimation of physiological or psychophysiological state.

For our convenience for future let's introduce non-empty set of indices of indicators:

$$I_S = \{1, 2, ..., n\}, \qquad (6)$$

$$I_{OS} = \{i \in I_S : p_i = 1\}. \qquad (7)$$

Being used (6) and (7), the sets $\{1, 2, ..., n\}$ and $\{x_i : p_i = 1\}$ let's introduce as

$$\{x_i : i \in I_S\}, \qquad (8)$$

$$\{x_i : i \in I_{OS}\}. \qquad (9)$$

Then the previously formulated task of constructing an estimation of the physiological and psychophysiological state of the system S can be formulated as follows: on the set of parameters (9) to conduct an analysis of experimental data for the system S, and to obtain an integrated estimation of the state of system V_S, which should indicate the degree of output of indicators $x_i : i \in I_{OS}$ in the field of pathological values, which are determined by α_i and β_i.

It is clear that even with such a statement, evaluation V_S can be obtained by various methods. Specificity of the choice of method depends on the requirements for informativity of evaluation V_S. As already noted, the algorithms for constructing of the estimation V_S are based on the use of regression models like

$$V_S = \sum_{i \in I_{OS}} \gamma_i \cdot \bar{x}_i, \qquad (10)$$

where $\bar{x}_i$ are unified standardized indicators of system V_S, γ_i are the weighting coefficients.

The choice of the weighting coefficients is based usually on the knowledge about the significance or the level of input of x_i in comparison with other indices. For the determination the following hypotheses were used. The first one indicates that the weight of the coefficient x_i is the higher, the higher the ratio of the ranges "norm" (2) to the length of total interval (1). And if this hypothesis is true for all $x_i : i \in I_{OS}$, then in this case γ_i count according to equations:

$$\gamma_i = \frac{k_i}{\sum_{i \in I_{OS}} k_i}, \qquad (11)$$

$$k_i = \frac{x^n_{i_{\max}} - x^n_{i_{\min}}}{x_{i_{\max}} - x_{i_{\min}}}, \ i \in I_{OS}. \qquad (12)$$

In the case when the second (the inverse of the first) hypothesis is taken, which is that the weight of the indicator x_i is the higher, the less the ratio k_i calculated according to (12), and this is true for all $x_i : i \in I_{OS}$, then γ_i is determined by the equation

$$\gamma_i = \frac{1}{k_i \sum_{i \in I_{OS}} 1 / k_i}, \ i \in I_{OS}. \qquad (13)$$

Sure, the algorithms (11) – (13) of the calculation of weight are easily generalized for the case, when one part of the indicators x_i, $i \in I_1 \in I_{OS}$ is the subject to the first hypothesis, while other indicators x_i, $i \in I_2 \in I_{OS} (I_1 \cup I_2 \equiv I_{OS})$ are determined by the second hypothesis:

$$\gamma_i = \begin{cases} k_i / A_{OS}, & i \in I_1, \\ 1 / k_i \cdot A_{OS}, & i \in I_2, \end{cases} \qquad (14)$$

$$A_{OS} = \sum_{j \in I_1} k_j + \sum_{j \in I_2} \frac{1}{k_j}. \qquad (15)$$

During the implementation of the algorithm, the estimations V_S (in percents) of the deviations of the indices $x_i : i \in I_{OS}$ from the given intervals of the "norm" in the area of pathological values are calculated, as well as the integral estimation (in percents) of the degree of violation of the system as a whole.

Here is a brief description of the algorithm and its modifications.

As input data in algorithm are experimentally measured indices $x_i : i \in I_{OS}$, their intervals "norm" $[x^n_{i_{\min}}, x^n_{i_{\max}}]$, intervals of possible change $[x_{i_{\min}}, x_{i_{\max}}]$ and the signs, introduced above α_i, β_i, p_i. Let's consider that for each x_i the value

$$x_i^0 = 0.5\left(x^n_{i_{\min}} + x^n_{i_{\max}}\right). \qquad (16)$$

From the point of view of the system functional state the optimal value s are $(x_{i_{\min}} \neq x_{i_{\max}})$. Let's consider that measured index x_i deviates from optimal value by 50 %, if x_i is equal to $x^n_{i_{\min}}$ or $x^n_{i_{\max}}$. Also, we will distinguish the sign of x_i deviation. If $x_i - x_i^0 > 0$, then the deviation x_i from x_i^0 is positive (deviation to the right), and vice versa, if $x_i - x_i^0 < 0$ the deviation x_i^0 is negative.

The real deviation of x_i from x_i^0 in the values, in which the given input measured values are denoted by Δx_i, which is determined by

$$\Delta x_i = x_i - x_i^0. \qquad (17)$$

Relative deviation x_i (in %) is calculated by the equation

$$P_{\Delta x_i} = \frac{\Delta x_i}{x^n_{i_{\max}} - x^n_{i_{\min}}} \cdot 100\%. \qquad (18)$$

Value $P_{\Delta x_i}$ will be considered as estimation V_{x_i} of the indicator x_i:

$$V_{x_i} = P_{\Delta x_i} \qquad (19)$$

Thus, using the formulas (17), (18), for each measured parameter $x_i : i \in I_{OS}$ we obtain a system of estimations V_{x_i}, $i \in I_{OS}$, according to which it is already possible to decide about the deviation degree of system S from the optimal values x_i^0.

An algorithm for obtaining V_S estimation is proposed to be constructed on the base of the hypothesis about the equivalence of estimations V_{x_i} previously determined by formulas (17) – (19). Let's note that from this hypothesis does not follow the equivalence of parameters $x_i : i \in I_{OS}$, but it allows us to calculate V_S with the same weight coefficients in accordance with the following rule of the solution:

$$V_S = \frac{1}{r_{OS}} \sum_{i \in I_{OS}} \left| V_{x_i} \right|, \tag{20}$$

where r_{OS} is the dimension of the set I_{OS}.

The estimation (20) is an integral one. It is constructed basing on the values of deviations of all parameters from nominal values, which were previously defined as optimal and equal to x_i^0. Here the assumption is made that the deviation from x_i^0 to any side worsens the state of a system with equal force, which depends on the absolute value V_{x_i}. For the researcher V_S is an important integral indicator of the system S functioning, which can be used in combination with estimations V_{x_i}. Let's note that V_{x_i} indicates the degree of deviation of the indicator x_i (in %) from its nominal value, and sign of the estimation V_{x_i} is the direction of deviation (right or left) from the nominal point.

A more informative integral index of output degree of system S parameters in the area of pathological values is the estimation V_S, which is constructed according to the equation

$$V_S = \begin{cases} \dfrac{1}{r_{OS}} \cdot \sum\limits_{i \in I_{1OS}} \left(\left| V_{x_i} \right| - 50 \right), & r_{1OS} \neq 0, \\ 0, & r_{1OS} = 0, \end{cases} \tag{21}$$

where I_{1OS} is the set of indices of parameters $x_i : i \in I_{OS}$, that are measured in an experiment. Their values are rejected in the area of pathological values, r_{1OS} is the dimension of the set I_{1OS}, the number of those $x_i : i \in I_{OS}$, whose values are pathological. Let's note that the estimation V_S, obtained by equation (21) is based on values V_{x_i} for which one of the conditions is true:

$$V_{x_i} < -50\%, \; p_i = 1, \; \alpha_i = 1, \tag{22}$$

$$V_{x_i} > 50\%, \; p_i = 1, \; \beta_i = 1. \tag{23}$$

The set I_{1OS} used in (21) is formed according to (22), (23).

In the case where the hypothesis of equivalence of estimations V_{x_i} is disputed, it is necessary to use weight coefficients and to solve the task of their determination. Taking into account the weight factors, the estimation V_S in the formulation given above, is calculated according to equation

$$V_S = \begin{cases} \dfrac{1}{r_{OS}} \cdot \sum\limits_{i \in I_{1OS}} \gamma_i \left(\left| V_{x_i} \right| - 50 \right), & r_{1OS} \neq 0, \\ 0, & r_{1OS} = 0. \end{cases} \tag{24}$$

Weights coefficients $\gamma_i > 0$, $i \in I_{OS}$ should be normalized, which means that

$$\sum_{i \in I_{OS}} \gamma_i = 1. \tag{25}$$

The procedure for normalizing of weight coefficients is simple indeed, if previously the initial output coefficients γ_i^0 are known for all $i \in I_{OS}$

$$\gamma_i = \frac{\gamma_i^0}{\sum\limits_{j \in I_{OS}} \gamma_j^0}, \quad i \in I_{OS}. \tag{26}$$

So, the relation (26) permits to calculate the normalized weight coefficients that are used in (24) for those group of indices x_i, for which $i \in I_{OS}$.

Let's turn to the problem of obtaining of integral estimation of the physiological and psychophysiological state of organism, whose status, as already noted, consists on the number of physiological and psychophysiological subsystems, which we identify with systems of type S. Let's consider that the number of such systems S, which define the physiological and psychophysiological status of an organism, is equal to m. Using the algorithm described above, we can obtain estimations V_{S_i}, $i = 1, 2, ..., m$. For the obtaining of integral estimation of the physiological and psychophysiological state of organism, the linearly weighted function is proposed:

$$V_{FS} = \sum_{i=1}^{m} \delta_i V_{S_i}, \tag{27}$$

where V_{FS} is estimation of the physiological and psychophysiological state of organism; δ_i are weight cweight coefficients of systems $S_1, S_2, ..., S_m$.

The practice of using of relation (27) to obtain of an integral estimation of the physiological and psychophysiological state of organism demonstrates that subsystems that make up the physiological and psychophysiological organism state are equivalent (or practically equivalent). Therefore, the task of determining of weight coefficients δ_i disappears, and in this case the estimation V_{FS} is based on equation

$$V_{FS} = \frac{1}{m}\sum_{i=1}^{m} V_{S_i}. \quad (28)$$

In article [14], it was substantiated in detail that special physical training solves successfully the tasks for certain periods of increasing the professional skill of flight crews – re-training for a new type of aircrafts (or helicopters), practice in flights at low and extremely low altitudes, restoring of pilot skills after a long break in flying activities. The purpose of physical training is in formation of physical and psychological pilot readiness to study the complex aircraft technology, its effective use, and high psychophysiological reliability of organism in terms of training and combat activities. In order to assess the quality of this training we propose to apply suggested algorithm for processing of data models. As data models we propose to use the data that characterize the subsystems of the functional state of organism, including the subsystem of special work ability of pilots [8] – [10], the subsystem that determines the functional state of organism by means of electrical signals [6], [7], the subsystems that characterize the state of the functional respiratory system [15], and the subsystem of psychophysiological indicators [8].

IV. Conclusion

The proposed algorithm can be used for the development of information and diagnostic system designed for automatizing of collection, storage and processing of physiological and psychophysiological data for services of preventive medical examinations. A separated task of elaborated system is the task of forecasting of the physiological and psychophysiological state of organism of the members of flight crews, which is solved according to realized algorithm.

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Н. І. Аралова, О. М. Ключко, В. Й. Машкін, І. В. Машкіна. Алгоритми обробки моделей даних для інтегральної оцінки стану осіб льотного складу

Запропоновано алгоритм обробки моделей даних для оцінювання фізичного, психофізіологічного та функціонального стану членів льотних екіпажів, який може бути використаний при розробці информаційно-діагностичної системи, призначеної для автоматизації збору, зберігання і оброблення інформації фізіологічних і психофізіологічних даних служби профілактичних медичних оглядів осіб льотного складу. Існує низка інформаційних технологій, які об'єднують комплекси пристроїв і методів для визначення психологічних і психофізіологічних характеристик операторів в процесі їх професійної діяльності в даний час. Виконана робота може бути використана при розробці інформаційно-діагностичної системи, призначеної для автоматичного збору, зберігання і обробки фізіологічних і психофізіологічних даних для профілактичних медичних оглядів для персоналу льотних екіпажів.

Ключові слова: функціональний стан оператора; працездатність оператора; інтегральна оцінка; регресійна модель; оцінка стану осіб льотного складу.

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Н. И. Аралова, Е. М. Ключко, В. И. Машкин, И. В. Машкина. Алгоритмы обработки моделей данных для интегральной оценки состояния персон летного состава

Предложен алгоритм обработки моделей данных для оценки физического, психофизиологического и функционального состояния членов летных экипажей, который может быть использован при разработке информационно-диагностической системы, предназначенной для автоматизации сбора, хранения и обработки информации физиологических и психофизиологических данных службы профилактических медицинских осмотров лиц летного состава. Существует ряд информационных технологий, которые объединяют комплексы устройств и методов для определения психологических и психофизиологических характеристик операторов в процессе их профессиональной деятельности в настоящее время. Проделанная работа может быть использована при разработке информационно-диагностической системы, предназначенной для автоматического сбора, хранения и обработки физиологических и психофизиологических данных для профилактических медицинских осмотров для персонала летных экипажей.
Ключевые слова: функциональное состояние оператора; работоспособность; интегральная оценка; регрессионная модель; оценка состояния персон летного состава.

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