Structuring Information about the State of the Cyber-Physical System Operator

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Cyber-physical systems - real-time robust systems with high performance and reliability requirements. Such systems are fundamentally distributed and are characterized by high saturation of sensors and actuators. They provide automatic operation of complex technical objects and reduce the operating personnel of production systems to a minimum.
Human interaction with information technology systems in such a high-tech environment is becoming more complex and diverse, which creates significant loads and this can also negatively affect his performance. It is necessary to constantly monitor the state of all components, including the functional state of the human operator. At the same time, an important problem is the structuring of heterogeneous information, which is recorded during the monitoring process and is used to assess and predict changes in the state of the human operator.
In the general case, human state monitoring systems allow to integrate a variety of information about the factors affecting his health.

At monitoring, information processes of data collection, transfer, storage and processing are implemented, which are necessary for the formation and decision-making about the state of the human operator.

A special place is occupied by remote monitoring, which allows you to monitor the health of people who are outside the medical institution.

Fig. 2. Information processes at monitoring
The sources of primary information for assessing the human state are various sensors that allow to record biosignals.

At monitoring, significant indicators of the functions and adaptive reserves of the human body are compared with standards, and then an assessment of the condition is given.

Thus, monitoring systems of the human body, collecting a large amount of heterogeneous data, are the basis for the integration of knowledge about the state of his health.

**Fig. 3. The main components of the remote monitoring system**
Features of structuring the flow of heterogeneous data to assess the operator’s state

Regardless of the data channel used, the monitoring system receives a huge amount of information of various types. This entire data array characterizes the same person and contains potential knowledge about the state of his body.

In order to structure and identify patterns from the flow of heterogeneous information, data is merged or integrated. The key feature of information integration is that human operator activity is characterized by various indicators that determine his state. The difficulty lies in the fact that the measured values have different nature, units of measurement and ranges of variation.
The main stages of the process of assessing the state of a human operator are:

- registration of current data on the results of monitoring;
- primary processing of heterogeneous data;
- grouping and ordering of data, including their rationing and coding;
- selection of informative indicators, including those that have the greatest impact on the performance of a human operator;
- choice of technology for analyzing structured data;
- establishment of interrelation between informative indicators and classes of a person’s functional state (using a trained model);
- assessment of the human operator state and the forecast its change.
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As a first example, we consider the use of biosignals for assessing a person’s state.

Let us consider a mathematical model based on a sphygmogram, which records fluctuations in the arterial wall of a vessel caused by the release of a shock volume of blood into the arterial bed. Using the principle of basic models of oscillatory systems, taking into account the biomechanics of the vessel, it is possible to describe the dynamic properties of the vascular wall by the Van der Pol - Rayleigh equation:

\[
\ddot{x} + \left[ \varepsilon_1 (x^2 - r^2) + \varepsilon_2 (\dot{x}^2 - \omega_0^2 \cdot r^2) \right] \cdot \dot{x} + ax = P(\omega_0 t) \tag{1}
\]
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There are the signals of pulse activity $x$ and electrical activity of the heart $e$ at rest (solid line) and at psycho-emotional stress (dashed line). It is seen that in addition to increase the frequency, the shape of the curves changes to a certain extent.

The proposed model (1) distinguishes these states, since they correspond to different values of the model parameters $a$, $\varepsilon_1$, and $\varepsilon_2$.

Thus, for the rest state of the human operator, the values are obtained:

$\varepsilon_1 = -0.3; \varepsilon_2 = -3.37; a = 36.15$.

For the same person under stress, the parameters received values:

$\varepsilon_1 = -1.07; \varepsilon_2 = -8.31; a = 95.5$.
We consider the problem of predicting the development of peptic ulcer disease. Let us imagine the human body as a complex dynamic system in the form:

\[ S = \{X, A, V\} \]

- \(X\) - the vector of system state variables, or the vector of symptoms;
- \(V\) - the vector of disturbing influences;
- \(A\) - a set of parameters characterizing the system properties.

Moreover, there is a group of parameters \(a_i\), reflecting the sensitivity of the system to one particular class of external disturbances.

In this problem, \(a_i\) are psychological and other indicators characterizing the body's reactions to stress disturbances \(V_1\). Since the values of these disturbances are unknown, it is assumed that their level is constant.
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The problem is as follows: under the action of constant disturbances $V_1$, based on the indicators $a_i$, which are measured on different scales, to make a forecast about the probability of peptic ulcer disease.

As parameters $a_i$, we use the results of psychological testing, grouped by six indicators and coded:

- Severity of emotional stress
- Level of performance loss;
- Strength of nervous processes
- Balance of nervous processes
- Holmes social adaptation scale
- Toronto scale of alexithymia
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The first layer is an element of the radial basis function (RBF) network. Each of the neurons of the first layer carries information about a particular cluster (group of people) of the training sample.

The second layer is feed-forward perceptron (FFP) with a binary sigmoid restriction function.

Fig. 6. Developed network topology
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Fig. 7. Dynamics of the network learning process

Fig. 8. Fragment of the system working
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Thus, the predisposition of people to serious disease can be realized by applying universal psycho-physiological tests and using information obtained without medical examination. This is important when assessing the state of the human operator and when choosing the nature of its production activities. Therefore, tests can be used in the organization of targeted preventive measures, which significantly increases their effectiveness while reducing overall costs.
The article focuses on the activity of the operator of the cyber-physical system, which is accompanied by high psycho-emotional stress and can negatively affect its performance.

Therefore, the necessity of monitoring the functional state of a person, during which large amounts of data are collected, is justified.

The collected information contains potential knowledge about the state of health, and its extraction requires the preliminary structuring of heterogeneous information, which is then used to assess and predict changes in the state of the human operator.

Examples of various problems for assessing the human state are given and the features of structuring heterogeneous data are noted.
Thank you for attention!

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