The automated system for prevention of industrial-caused diseases

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Abstract. The paper presents the automated system intended to prevent industrial-caused diseases of workers, the basis of which is represented by algorithms of preventing several negative functional conditions (stress, monotony). The emergence of such state shall be determined based on an analysis of bioelectric signals, in particular, skin-galvanic reactions. Proceeding from the dynamics of the functional state, the automated system offers to perform an optimized set of measures to restore the health of the worker. Implementation of an automated system is presented in Visual Programming system LabVIEW.

1. Introduction

The optimum functional state of a worker contributes to the high productivity and quality of activities results. Under the influence of negative factors or an irrational labor mode, the functional state and its transition into the negative one, for example, stress, monotony, happen. The emergence of such conditions leads to deterioration of health, reduction of the efficiency of the workforce and a decrease of the quality of the result of the work.

It is known that the deterioration of the workers’ health entails great economic losses: the growth of insurance premiums; direct medical costs, training employees to replace the retired members due to accidents, injuries, and reduced productivity [1, 2].

In Russia, the annual economic loss due to injury at work and an occupational disease is about 407.8 billion rubles (1.9% of GDP). At the moment, the Russian able-bodied population mortality 4.5 times higher than EU one, and over the next decade it can reach in perspective more than 10 million human. From 20 to 40% labor losses are attributable to diseases directly or indirectly related to the unsatisfactory working conditions, more than 20% of the total working population are certified as disabled for the first time at the age of 45-50 years.

Industrial-caused morbidity is the morbidity (age-standardized) common diseases of different etiology (polietiologichesky), which has a tendency to increase the number of cases increasing with seniority in harmful or dangerous working conditions and exceeding it in groups, not in contact with harmful factors.

Professional morbidity is a measure of the number of newly diagnosed patients during the year with occupational diseases and poisonings, calculated per 100, 1000, 10000, 100000 workers. An occupational disease is a chronic or acute illness of the worker resulting from exposure to a harmful production factor (factors) and resulting in a temporary or persistent loss of their professional ability to work.
As an example, manifestations of industrial-caused diseases include "Office syndrome". This term is used to describe disorders among workers in sedentary occupations.

For example, the number of diseases of the musculoskeletal system grows every year and ranges from 8 to 13% for office employees. Also, peculiar to premature aging (on average 10 years earlier), serious metabolic changes in the body, resulting in not only a set of weight loss, but also in the suffer from blood vessels, eyes, spine, which may also develop muscular-skeletal pain in the back, neck, upper extremities, headache, a "computer mouse" syndrome, a "dry eye" syndrome, etc. [3, 4].

Thus, the urgent task of monitoring the status of a worker, preventing negative functional states and resolve, has already emerged, aimed at fighting with the emergence of occupational and industrial-caused diseases.

At the moment, there are technical proposals to reduce the influence of the human factor of the operator on the production. However, healthsaving of workers and a combat of the negative effects of work is decided holding a narrow range of organizational-technical actions or is not solved at all [5, 6].

The problem of the preservation of the workers health and prevention of negative and industrial-caused states could be solved by:
1. the development of algorithms for the estimation of the functional state of the workers;
2. the choice of restorative procedures for correction and prevention of negative functional states;
3. the development of tools for automating the process of prevention of industrial-caused diseases.

The aim of this work is to develop methods and advances to prevent the industrial-caused diseases of workers.

The task of creating a tool to automate the processes of healthsaving and prevention of the industrial-caused diseases of workers can be solved using National Instruments technology, in particular when implementing hardware, which uses data acquisition board USB-6008, and for the software - visual programming environment LabVIEW.

2. Materials and methods

Monitoring the functional state of a worker may be based on the analysis of bioelectric signals [7-9]. It is possible to use skin-galvanic response (GSR) or electrodermal resistance as such a signal, which analysis will estimate the change of the psychoemotional state, which is particularly important, for example, for intellectuals, working on a computer [9].

The signal skin-galvanic reaction consists of two components: tonic and phasic. The tonic reaction – a low frequency component characterizes the psychoemotional state of a worker. Consequently, less than the resistance of the skin, the higher nervous system activity, increased skin resistance is indicative of worker fatigue. The phasic reaction – a high frequency component characterizes the signal fluctuations under the influence of emotionally relevant factors. Accordingly, a large number of signal oscillations per unit time may indicate a negative impact on the worker's current psychoemotional factors. Using an aggregate of phasic and tonic components, it is possible to conclude about the current functional state of the worker.

The following algorithm for analyzing the skin-galvanic reaction and determination of the level of psychoemotional tension of the worker is developed. Values and variables are provided by:

- \( W \) - the width of the smoothing window, ms,
- \( \Delta t \) - the sampling period,
- \( n \) - the sample size,
- \( x_k \) - the current value of electrodermal resistance,
- \( k \) - the reference number,
- \( x_{ck} \) – the value of the constant component at step \( k \),
- \( y_k \) - moments of electrodermal activity,
- \( \Delta y \) – the specified threshold for electrodermal activity,
- \( z_\alpha \) - the deadzone,
- \( N_L \) - the number of jumps,
1. Continuous measurement of electrodermal resistance \( x_k \) at each step \( k \). Filtering the received signal.

2. Initial processing of recorded dependencies of electrodermal resistance on time. Here, we calculate constant component (level) \( x_{c_k} \) of dependence of resistance on time. Calculation of the constant component is performed by averaging the sample values from the array of electrodermal impedance:

\[
x_{c_k} := \frac{1}{n} \sum_{i=k-n}^k x_i.
\]

Sample size \( n \) is determined by dividing the value of \( W \) by time sampling period \( \Delta t \):

\[
n = \frac{W}{\Delta t}.
\]

Primary processing includes steps for the formation of an array of values of electrodermal resistance and array of the constant level of electrodermal resistance. Let us specify the fixed-size arrays. The new values of the resistances upgrade the contents of the arrays. In the future, arrays are displayed in a graphical form of the automated system.

3. Let us select electrodermal activity points (fasic component). Using arrays of values of electrodermal resistance and a constant level of resistance is determined by electrodermal moments of electrodermal activity \( y_k \). Electrodermal activity from a physiological perspective is leap body resistance between electrodes. The existence of the jump determines the largest difference between the current value of resistance \( x_k \) and the current value of level \( x_{c_k} \). In case of exceeding specified threshold \( \Delta y \), the provisional value of that «activity» is assigned to the value "True", otherwise "False":

\[
y_k = \begin{cases} 
\text{False}, & \text{if } x_k - x_{c_k} \leq \Delta y, \\
\text{True}, & \text{if } x_k - x_{c_k} > \Delta y.
\end{cases}
\]

Thus, with the appearance of the jump in resistance, the impetus is formed, the duration of which depends on the speed of recovery of the reference magnitude of resistance. Exclusion of a debounce introduces neutral zone \( z_n \). An array of "Moments of the appearance activity" is formed here, The value of this array of Boolean elements will be true at the time of the change of the zero single array activity. The final step is to update the array "Activity" and "Moments of the appearance activity".

4. Analysis of the current level of agitation of the worker. It is proposed that the current level of excitement of the worker is defined as a number of resistance jumps \( L \) in specified time interval \( t \). For the computation, we should calculate the average during the observation of the number of values "True" \( N_L \) in the array of «Moments the appearance of activity»:

\[
L := \frac{N_L}{t}.
\]

Analysis involves comparing the current level of the excitation operator with some thresholds \( m_1 \) and \( m_2 \). If the level of excitement will be unacceptably low or excessively high, it generates alarm signal \( r_k \):

\[
r_k = \begin{cases} 
1, & \text{if } m_1 < L < m_2 \text{ or } m_1 > L, \\
0, & \text{if } m_2 \leq L \leq m_1.
\end{cases}
\]

The number of jumps of magnitude electrodermal resistance monitored per time unit determines the level of psychological tension or activity of the nervous system of the worker.

5. Fixation of the most significant events. It is proposed to capture the moments in time when the level of excitement is critically low or excessively high, and moments in time restore the level of arousal to an acceptable value. Thus, it is possible to detect the emergence of monotony, fatigue and
stress.

6. Cyclical execution of pp. 1-5 until analysis SGR and worker state are determined.

**Prevention of industrial-caused diseases**

Under prevention of industrial-caused diseases is meant a set of activities aimed at preventing the development or elimination (full or partial) already emerged negative functional states. There are a number of ways to improve or normalize the human condition. If we consider the activities of the employee working with a computer, it is possible to note the high level of load on the eyesight and the musculoskeletal system. This load can lead to the appearance of fatigue and rise of stress. And the negative condition may evolve at different speeds. It is therefore proposed to use such corrective activities as passive restoration, audio-visual correction, gymnastics for the eyes and the industrial gymnastics.

It is proposed to link the signal of SGR dynamics with views of corrective activities. In Table 1 represents the dependence of the type of corrective activities on the dynamics of electrodermal impedance.

**Table 1. The proposed link of corrective activities with dynamics of electrodermal resistance**

| Tonic component | Fasic component | Time of changes in state | Corrective activities |
|-----------------|-----------------|--------------------------|-----------------------|
| The value is large | The number of jumps is small | Less than 30 minutes | Passive restoration |
| The value is average | The number of jumps is large | Less than 30 minutes | Passive restoration |
| The value is small | The number of jumps is large | Over 2 hours | Audio-visual correction |
| The value is small | The number of jumps is large | Less than 30 minutes | Passive restoration |
| The value is average | The number of jumps is small | 40 minutes | Gymnastics for the eyes |
| The value is large | The number of jumps is small | Over 2 hours | Industrial gymnastics |

1. Passive recovery (rest) of worker. This program is run, if fatigue came quickly and the duration of the recovery was planned. In this mode the system starts the timer which is counting down the time of passive recreation of a worker.

2. Exercises for the eyes are aimed at restoring the eyesight. This program starts when a mental labour worker works at the computer for 40 min, unless fatigue arises. In this mode, the system prompts a person to perform a few exercises to restore the sight and to overcome the overstrain and fatigue.

3. Industrial exercises are aimed at restoring health and combat the monotony due to the activation of different muscle groups. This program is triggered if fatigue has developed for a long time. In this mode, the system prompts a person to perform several exercises designed to improve the muscle tone of an employee.

The recovery mode continues until the value of the skin-galvanic reaction goes beyond the thresholds with some margin for 1 minute.

3. **An automated system for prevention support of industrial-caused diseases**

the automated system use the technology from National Instruments as the hardware and software
components. The hardware is based on data acquisition board USB-6008, and the software is the virtual instrument of LabVIEW. The front panel of the virtual instrument is presented in Figure 1.

![Figure 1](image1.png)

**Figure 1.** The front panel of the virtual instrument for monitoring the functional status of the worker

To organize removal of the skin-galvanic reaction, it is possible to use a modified mouse on the keyboard which is represented by the arranged electrodes (Figure 2).

![Figure 2](image2.png)

**Figure 2.** A modified mouse for the removal of the SGR

Signal transmission from USB-6008 is performed using the «DAQ Assistant Data» block. The received signal is filtered by a lowpass filter [10].

On the front panel of the virtual instrument there are 4 tabs. On the «Assessment of psycho-emotional state» tab, one can select the input threshold for the results of the evaluation of the functional status, indicators of the current functional status, the waveform window, elements of forecasting changes in the functional status. Elements of the "Change skin-galvanic reaction in time" display dynamic and instantaneous GSR of an employee.

It is possible to allocate the tonic and phasic components of the signal which are integrally compared to thresholds that are specified for each user of the automated system. The recognition of normal and following negative functional states is resulted: stress, emotional tension, fatigue, severe fatigue (sleeping).

The "Control" tab presents a diagram that shows the dynamics of the functional state during the day. This tab also displays the parameters and indicators of the workflow, including the time of work and rest, the statistics of the workflow.

The "Restoration" tab is activated when the employee raises the negative functional states. In this case, we must follow the instructions presented in the given inlay. The type of recovery activities
depends on the functional state and its dynamics over time: passive restoration, audio-visual correction, gymnastics for the eyes and the industrial gymnastics. For example, in Figure 3, the "Restoration" tab illustrates the implementation of the recovery system using gymnastics for the eyes.

![Gymnastics for the eyes](image)

Figure 3. The front panel of the recovery program using gymnastics for the eyes

4. Conclusion

The paper considers the problem of monitoring the employee state on the basis of the skin-galvanic reaction and preventing the negative functional states (stress, monotony) based on the results of such monitoring. Selected employee recovery activities are aimed at protection against monotony and stress depending on the dynamics of the skin-galvanic reaction during the day.

The variant system realization is based on methods in Visual Programming LabVIEW.

Using the developed automated system allows for monitoring the status of worker production and reduction of the risk of negative functional conditions and illnesses, including the musculoskeletal system among office workers.

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