Evaluation of psycho-emotional status of robotic system operator in the Arctic

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Abstract. The paper shows the algorithm to assess psycho-emotional status of robotic system operator in the Arctic. It is shown that modern direction of robotics development does not sufficiently take into account the peculiarities of operator work in polar conditions. As a result, the efficiency of operator work can be significantly reduced which may lead to accidents and disabling of robotic systems and, consequently, to an increase in the cost of operations. The paper shows the need for systematic monitoring of psycho-emotional operator status. Modern methods to assess psycho-emotional state of a person in extreme conditions are considered and the assessment by speech signal is shown to be the most appropriate one. At the same time, other methods to assess psycho-emotional status of a person, such as assessment of heart rate and electrical activity of the skin, as well as assessment of facial expressions and body movement, have features that limit their use to assess operator status in the Arctic. The approach to assess psycho-emotional status of a person in the Arctic based on two-dimensional model of emotional plane is proposed, the effectiveness of these models. The possibility of using the proposed method for evaluating the psycho-emotional state of the operator under the conditions of the Arctic.

1. Introduction
The development of robotic systems (RS) in the Arctic is undergoing rapid growth. Every year an increasing number of developers offer their versions of devices designed to replace a person when working in harsh climatic conditions. However, no matter how modern and multifunctional the latest developments are, the moment when human resources can be completely excluded from work will not come soon.

Large amount of information that RS control is much easier on the territory of the Arctic than in the city can be found. In major metropolitan areas with many buildings around a large number of obstacles to the movement of robots as well as complicated interference environment can be noticed. In the Arctic, there are no such problems; therefore the movement of robots is simplified. This statement could be true if RS operators were in the same situation as when managing in urban environment. However, control systems of robots for operating at ultra-long distances, for example, in the conditions of the Arctic, have not yet been developed, which inevitably leads to the fact that an operator is forced to be located beyond the Arctic Circle.

In the development of RS designed to operate in the Arctic little attention is paid to the place of humans in future ecosystem. This creates a false impression that a person will be completely excluded from work in difficult polar conditions, and all work will be passed on to machines. This approach may lead to the fact that during implementation and operation of new systems the problems connected
with efficient operation of robots and their application to solve complex problems can arise. For successful RS start and usage in the Arctic the issues related to the peculiarities of RS control in difficult conditions are necessary to be considered.

2. Analysis of the problems associated with the work of RS operators in the Arctic

In recent years the number of specialists who work beyond the Arctic Circle [1] has increased, nowadays the basic principle of work is shift method when an employee or a soldier spends several months in the Arctic. This method assumes that the staff on mission is easier to live in extreme working conditions as recovery takes place in customary, home conditions. At the same time, studies [1] show that human adaptation to the conditions of the Arctic occurs over a longer time (up to 2 years), and the first months of work in new environment lead to stress and the so-called “winter-over” syndrome, one of the manifestations of which is a strong psycho-emotional change.

Research of “winter-over” syndrome influence on human health and performance shows the need for continuous monitoring of human condition, as well as preventive treatments to restore effective performance [2].

The introduction of modern RS allows us to solve more complex problems related to study and development of Arctic resources, but does not exclude human performance issues in the Arctic Circle for robot control and maintenance. Besides, the availability of modern computing systems at human disposal opens new possibilities for monitoring the state of people including operators of robotic systems.

Robot control in the Arctic means the presence of a person in a room and the use of remote control. This environment simplifies work and reduces the likelihood of injury or frostbite, but it does not affect the development of “winter-over” syndrome. Constant contact with RS control allows you to integrate into the system of operator state monitoring allowing in real time to evaluate general psycho-emotional status (PES) of a person and generate a warning signal in the event of a significant parameter deviation. As possible PES systems assessment the following approaches [3] can currently be used:

- evaluation of heart rate and skin electrical activity;
- assessment of facial expressions and body movements;
- speech signal (SS) evaluation.

The first approach implies the presence of special sensors mounted on a human body. This method, though, shows high results, but in real life situations it is difficult to install sensors that cause discomfort to a person.

The second approach is complicated by the fact that you need the exact position of a person's face in front of a high-quality camera. Due to the fact that all operator attention while operating RS should be focused on the task at hand, there is no possibility of permanent distraction of an operator to system camera. In addition, systems for assessing PES of facial expressions clearly distinguish basic emotional states, such as “joy”, “sadness”, “anger” and others, but are poorly applicable to the task of recognizing stress state.

The third approach involves the use of SS for assessing human PES. In this case, the system requires only a microphone to record operator's speech during operation. Given the fact that in the course of work an operator is often required to report the information on robot movements or about the objects detected, this option of obtaining data for assessing human PES is efficient.

3. Determining the efficiency of PES operator evaluation system

The use of SS for estimating human PES is of great interest due to minimum hardware requirements needed to run the system. On the other side, SS is a complex signal the parameters of which dynamically change with time. This fact greatly complicates the treatment of SS and the extraction of useful information for PES estimation, but the proposed methods make it possible to do this with sufficient accuracy [4].
The plane presented in Figure 1 is proposed as basic human PES model. Such representation of human emotions allows to relate them in two-dimensional space and to bind them to real numbers. The plane proposed in Figure 1 is based on a model plane of W. Wundt [5], but is suitable for evaluation of mathematical calculations, unlike the original model.

![Diagram](image)

**Figure 1. Basic emotional plane**

The research of human PES evaluation was conducted using the database recorded in Russian and including 460 records. At the same time, the database was divided into 2 parts: provoked emotions and real ones. The feature of provoked emotions is that such recordings were obtained as a result of prepared external influences on speakers, after which the speaker was required to utter a certain phrase. Such set of records reveals basic patterns and estimates the change of speech parameters with unchanged information and identification of speech components. The second part is a set of spontaneous phrases obtained from public sources, spoken by people who are in different emotional states. This part was used to test hypotheses about the significance of SS parameters for assessing human PES obtained as a result of working with the first part of the database.

As a result of estimating more than 100 parameters of SS, it was found that linear prediction coefficients and their derivatives are most efficient. To evaluate the efficiency a group method of data handling (GMDH) [6] was applied. The method involves the use of an inductive approach that consistently generates models of increasing complexity until you find a predetermined quality criterion model minimum. In general, the model uses the Kolmogorov-Gabor polynomial [7]:

$$y = a_0 + \sum_{i=1}^{m} a_i K_i + \sum_{i=1}^{m} \sum_{j=1}^{m} a_{ij} p_i p_j + \sum_{i=1}^{m} \sum_{j=1}^{m} \sum_{k=1}^{m} a_{ijk} p_i p_j p_k + \ldots,$$ (1)
where \( y \) – target emotion, \( a_i, a_j, a_{jk} \) – weights, \( p_1, p_2, \ldots, p_m \) – SS parameters.

The simulation was performed on two independent “pleasure-displeasure” and “relaxation-tension” scales, presented on the emotional plane (Figure 1). Based on the analysis of the results obtained during the processing of SS, the following models were singled out:

- For “pleasure-displeasure” scale:
  \[
  Y_1 = a_{10} + a_{11} \cdot K_{i=1}^2 + a_{12} \cdot K_{i=6} + a_{13} \cdot K_{i=8} \cdot \gamma_{2x},
  \]
  where \( K_{i=1} \) – i-th coefficients of impulse response of direct filter; \( \gamma_{2x} \) – kurtosis coefficient of the first derivative of SS; \( a_{10} = 0.0097, a_{11} = -0.0816, a_{12} = 0.3551, a_{13} = 0.0217 \).

- For “relaxation-tension” scale:
  \[
  Y_2 = a_{20} + a_{21} \cdot \bar{P}_x + a_{22} \cdot K_{i=p13} \cdot \bar{P}_x + a_{23} \cdot \bar{T}_x + a_{24} \cdot \bar{T}_x + a_{25} + a_{26} \cdot K_{i=p13} + a_{27} + K_{i=m2} + \\
  + a_{28} \cdot K_{i=m3},
  \]
  where \( K_{i=p1} \) – i-th linear prediction coefficient of SS; \( \bar{P}_x \) – average signal energy; \( \bar{T}_x \) – duration of voiced area; \( a_{20} = -0.3197, a_{21} = -0.0470, a_{22} = 1.0857, a_{23} = 7.3206, a_{24} = 6.8380, a_{25} = -3.3400, a_{26} = -57.2758, a_{27} = -19.7213, a_{28} = 0.0691 \).

The results showed that the models obtained allow classifying PES by “pleasure-displeasure” scale with a probability of 0.93, and by “relaxation-tension” scale with a probability of 0.83 [8].

When assessing operator PES, the main problem is the adaptation of basic emotional model to the model reflecting the features of a “winter-over” syndrome. According to studies [9], a “winter-over” syndrome is characterized by the stress of human body that is the result of long-term negative PES. The negative states on the emotional plane presented in Figure 1 include a lower left quadrant, which reflects the emotions of “displeasure” and “tension”. In accordance with this, when operating RS operator, it is necessary to monitor SS parameters with the aim to fix a long-term strong deviation of human PES in the direction of a left lower quadrant [10].

4. Conclusion

The studies found that the control of RS by an operator in the Arctic is accompanied by a greater strain on the operator than in normal urban or suburban areas. In this regard, it is advisable to use modern methods of assessing the state of an operator to maintain the efficiency of work at a high level. The results showed that the analysis of SS allows us to estimate operator PES with a probability of 0.83-0.93. Long-term monitoring of operator PES through the analysis of SS can help identify stress, which in turn allows taking timely actions.

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