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ЖҮРГІЗУШІНІҢ ШАРШАУЫН ТАНУ ҮШІН НЕЙРОНДЫҚ ЖЕЛІНІ ӘЗІРЛЕУДЕ ФИЗИОЛОГИЯЛЫҚ ДЕРЕКТЕРДІ ПАЙДАЛАНУ

ИСПОЛЬЗОВАНИЕ ФИЗИОЛОГИЧЕСКИХ ДАННЫХ ПРИ РАЗРАБОТКЕ НЕЙРОННОЙ СЕТИ ДЛЯ РАСПОЗНАВАНИЯ УСТАЛОСТИ ВОДИТЕЛЯ

PHYSIOLOGICAL DATA USE IN A NEURAL NETWORK DEVELOPMENT FOR DRIVER FATIGUE RECOGNITION

Андатпа. *Динамикалық жол ортасында автомобиль жүргізу сияқты монотонды күнделікті жұмыстармен жұмыс, адамнан үнемі бейімделуді және зейін қоюды қажет етеді. Ұйқышылдық немесе абайсыздық, сондай-ақ стресс немесе шамадан тыс психологиялық жүктеме сияқты монотонды әрекеттерге мұндай реакция қалыпты көлік жүргізу процесін бұзады. Бұл факторлар жүргізушіге үнемі өзгеріп отыратын жол оқиғаларына дұрыс жауап беруге кедергі келтіреді. Бұл жұмыста жүргізушінің қауіпсіз жұмысына әсер ететін ұйқышылдық пен стресстің объективті өлшемі анықталады, сонымен қатар жүргізушінің жағдайын бақылауға арналған бағдарламалық өнімді жасау үшін нейрондық желі жасалады. Сондай-ақ, жүргізушінің жағдайын жіктеуде физиологиялық деректерді белсенді пайдалану күтілуде, өйткені қазіргі заманғы автомобильдер автоматтандырылған басқару құралдарымен жабдықталған, бұл көлік жүргізуді құрылғыларды пассивті бақылаумен алмастыруға көмектеседі.*

Түйін сөздер: *модельдеу, адам жағдайы, бағдарламалау, нейрондық желілер, бейнеталдау.*

Аннотация. *Работы с монотонной рутинной деятельностью, такие как вождение автомобиля, в динамичной дорожной среде требуют от человека постоянной адаптации и сосредоточенности. Такая реакция на монотонную деятельность, как, например, сонливость или невнимательность, а также стресс или чрезмерная психологическая нагрузка нарушают нормальный процесс вождения. Эти факторы мешают водителю адекватно реагировать на постоянно меняющиеся дорожные события. В данной работе будет определена объективная мера сонливости и стресса, которые влияют на безопасную работу водителя, а также разработана нейронная сеть для создания программного продукта для слежения за состоянием водителя. Также ожидается более активное использования физиологических данных при классификации состояния водителя, потому что современные автомобили все лучше оснащаются автоматизированными средствами управления, которые помогают заменить вождение на пассивный надзор за приборами.*

Ключевые слова: *моделирование, состояние человека, программирование, нейронные сети, анализ изображений.*

***Abstract**. Works with monotonous routine activities, such as driving a car, in a dynamic road environment require a person to adapt and focus constantly. Reactions to monotonous activities, such as drowsiness or inattention, as well as stress or excessive psychological stress, disrupt the normal driving process. These factors make it difficult for the driver to respond adequately to ever-changing road events. In this article, an objective measure of drowsiness and stress that affect the safe work of the driver will be determined, and a neural network will be developed to create a software product for monitoring the driver's condition. Increased use of physiological data in driver condition classification is also expected because modern vehicles are increasingly equipped with automated controls that help replace driving with passive instrument supervision.*
***Keywords:** modeling, human condition, programming, neural networks, image analysis.*

Introduction. It can be said with confidence that the human factor is the main factor in more than 90% of road accidents according to the results of many studies [1, 2].

Nowadays, scientists continue to use subjective self-assessment scales in assessing the level of driver drowsiness, because there are no reliable and objective methods for determining the state of the driver. Thus, the development of methods, algorithms and other tools for understanding and monitoring human behavior in different situations and conditions is of great importance, which shows the relevance of the chosen research topic.

The purpose of this study: to develop an objective measure of fatigue and stress, which can subsequently be used to test and simulate traffic situations for decision-making.

The following tasks were identified in accordance with the goal:

1) analysis of methods to identify the state of drowsiness and stress of the driver;

2) modeling the recognition of the driver' dangerous behavior;

3) development of an algorithm for the computer program implementation.

Monitoring and alarming the driver about the dangerous condition, for example, falling asleep at the wheel, is a relevant and demanded task. The development of active safety systems is one of the ways to solve this problem. Identification of dangerous behavior or state of a person [3-6] while driving can draw the attention of the driver to his driving style, state of health, poor health, and assess the risks associated with this.Tthe rate of reckless driving will decrease, and many drivers will strive to improve their safe driving skills and driving behavior when these factors are taken into account.

An analysis of studies aimed at identifying drowsiness and stress showed that drowsiness is characterized by a slower reaction, reduced vigilance, and poorer information processing [7]. Driver drowsiness is a serious problem for road safety [8]. It is logical to ask how to measure driver sleepiness? Thus, the hypothesis of the study will be the presence of objective characteristics of driver drowsiness and stress to prevent dangerous driving situations.

Literature Review. The following tests are used to measure sleepiness in clinical settings:

- multiple sleep latency test (MSLT) [9] is the time it takes a person to fall asleep;
- the maintenance of wakefulness test (MWT) [10] measures how long a person can stay awake.

Both methods are used to diagnose sleep disorders and require the person to be immobile. Thus, they are not suitable for use in the process of driving a car. Subjective measurements of sleepiness based on self-reported data are commonly used in the real conditions of measuring sleepiness in humans.

There are two categories of sleepiness rating scales. The following scales are used to assess sleepiness at a particular point in time:

- Stanford Sleepiness Scale (SSS) [11];
- Carolina Sleepiness Scale (KSS) [12].

It is used to measure total sleepiness throughout the day:
- Epworth Sleepiness Scale (ESS) [13]
- wakefulness test the Sleep-Wake Activity Inventory (SWAI) [14].

In this study, subjective sleepiness is measured using KSS. This method allows to measure sleepiness in real time, taking into account the circadian rhythm and the environment. The recognition of a dangerous behavior (state) of a driver, a method for automatic processing of electroencephalogram (EEG) data was developed to realize the task of modeling.

Today there are many smart devices that allow receiving EEG data without special sensors and complex equipment that interferes with a person when driving. Examples of such devices are various smart watches, bracelets, etc. These devices are convenient to wear on the driver's hand; they do not distract a person from the process of driving a car, and do not restrict movement, thus do not cause additional inconvenience and do not affect driving safety. Xiaomi smart bracelet was used for the experiment.

Materials and methods of research. Now there are several methods used in hardware and software systems to assess the functional state of a person (see Figure 1).

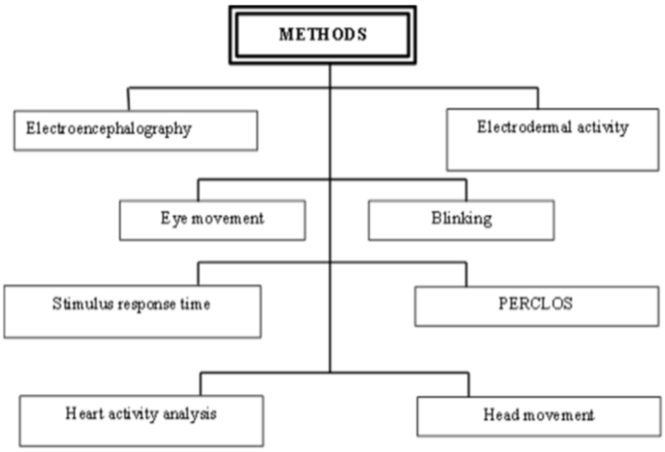


Figure 1. Methods used to assess the functional state of a person

Although many signals can be used to assess driver fatigue, electroencephalogram (EEG) data is one of the most predictive and reliable indicators because it directly measures brain activity [15].

This is how the smart bracelet screen looks like for determining sleep phases based on EEG (see Figure 2).

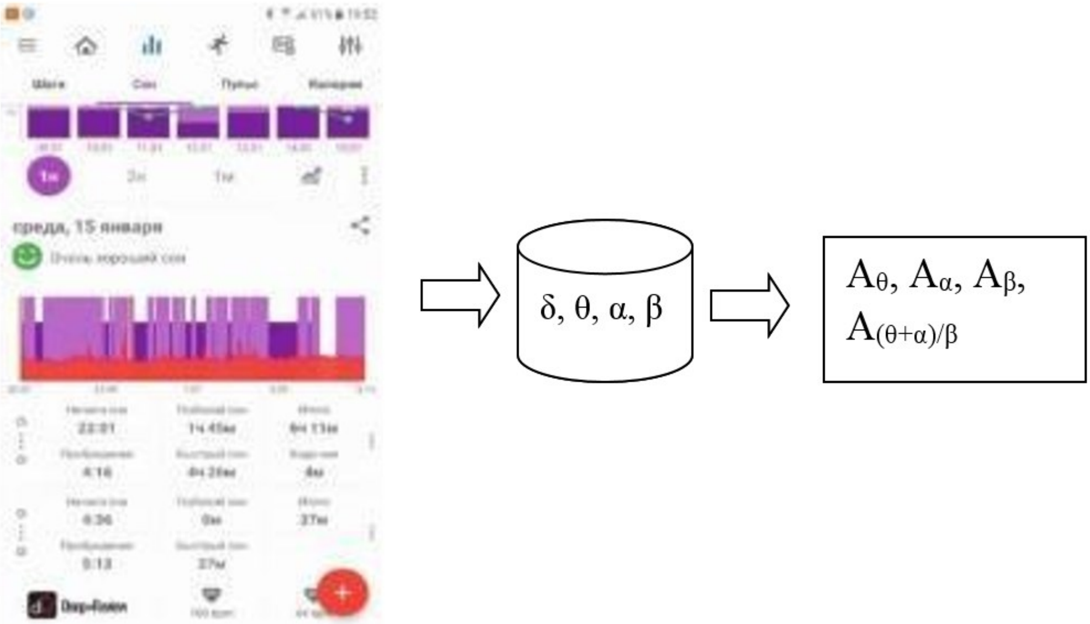


Figure 2. Data transfer from smart bracelet

When analyzing the readings of EEG frequencies for this study the frequency from 0.3 to 20 Hz is interesting, i.e. four bands: δ, θ, α and β. The δ band usually appears in the deep sleep state, so it was not used here.

We use the fast Fourier transform to obtain the average power spectra of the theta, alpha and beta ranges: A_θ, A_α, A_β, and $A_{(\theta+\alpha)/\beta}$ is the power spectrum ratio, which is used to estimate driver fatigue [16].

$$A_{(\theta+\alpha)/\beta} = \frac{A_\theta + A_\alpha}{A_\beta}$$

Let us introduce the following notation and formalize the problem posed.

We will use the standard three-dimensional coordinate system X, Y, Z.

Let's designate the movements of the driver's head as H_{mr}, where m can take the following values:

- x, y, z when moving along the corresponding axes,
- r is used to describe complex movements in space, for example, moving the head forward and down at the same time.

The driver's body can also move along the corresponding axes.

The image of a person in a car is taken from the site depositfiles.com, the designations are ours (see Figure 3).

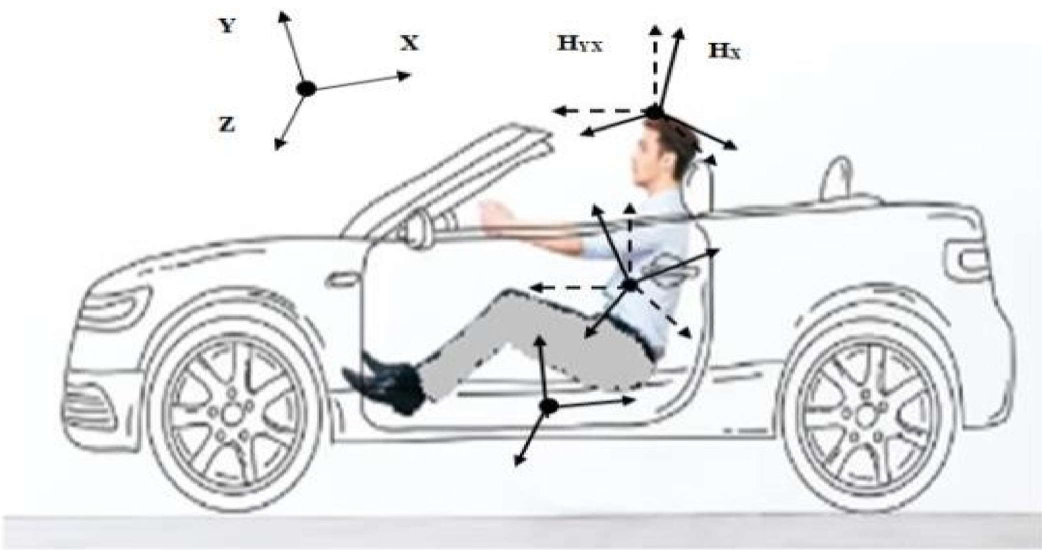


Figure 3. The location of the driver in the car and the axis of movement

The parameters characterizing the position of the driver's head are the angle of inclination and the angle of rotation of the head. The algorithm of camera calibration is shown in Figure 4.

In this calibration mode, the driver's head deviation angle is calculated with respect to the plane of the front camera of the smartphone. This information about the position of the head allows to detect a dangerous deviation of the angle of inclination / rotation of the head from the one specified in the application settings. Determining the angle of rotation / inclination of the driver's head:

```
Begin
1. diff ← dAngle - offsetAnglePref
2. cAngle ← diff * (if diff < 0) do (-1) else 1)
3. isDangerAngle ← cAngle > anglePref or cAngle < -angePref
End
```

where

- dAngle is the recognized angle of head rotation/tilt relative to the camera plane,
- offsetAnglePref is the angle of deviation of the head rotation/tilt from zero degrees,
- anglePref is the allowable head rotation/tilt angle (non-negative value),
- cAngle is the driver’s head position angle, taking into account the specified deviation.

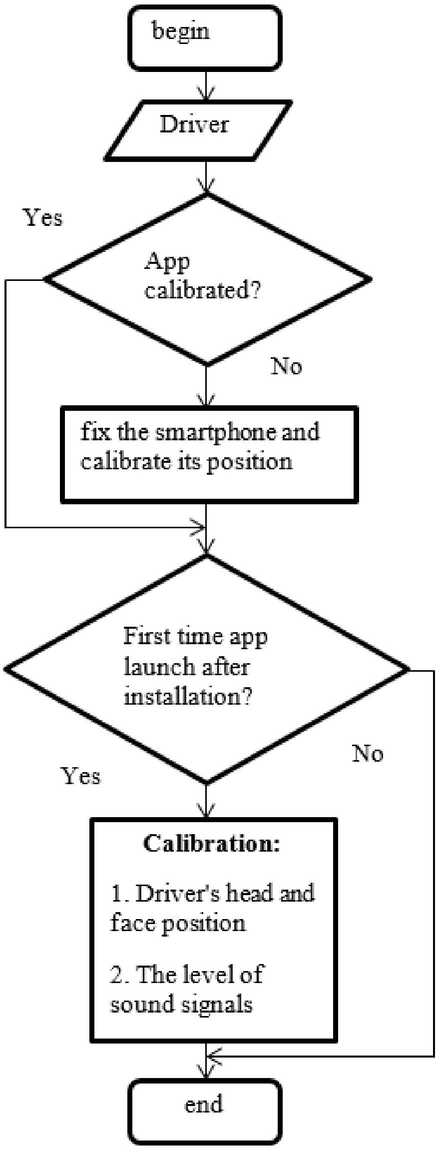


Figure 4. Manual calibration algorithm

A combination of several methods was used to development the neural network. Indicators of the PERCLOS method have been added, which allow to track the percentage of driver eye closure, as well as an analysis of the frequency of yawning. The Figure 5 shows the visualization of eye orientations.

At the top left in Figure 5 the eye is open. Upper right eye closed. At the bottom of Figure 5 is a graph of the change in aspect ratio over time. A drop in the aspect ratio of the eye indicates blinking [17].

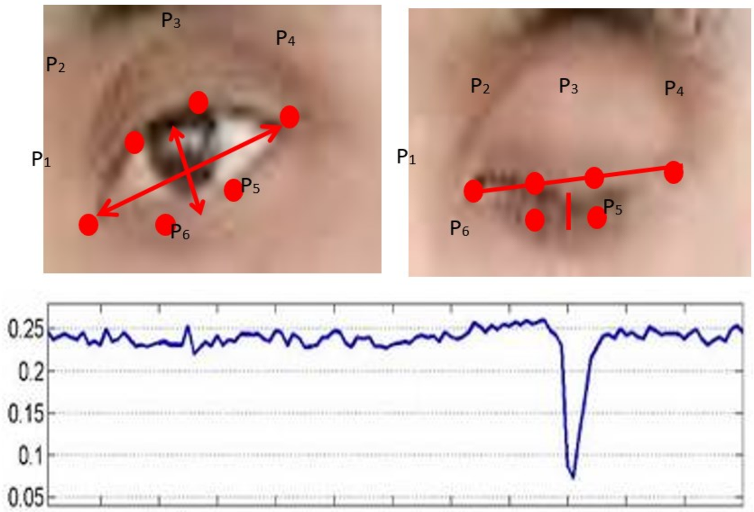


Figure 5. The visualization of eye orientations

We looked in detail at the process of tracking the aspect ratio of the eyes to see if this value drops, but also increases again In research papers [17, 18]. Next, the following variables are defined for the thresholds: two constants are defined for blink detection and for the number of consecutive frames; if the number of frames with closed eyes does not exceed the threshold value, then no alarm is triggered;

If the number of frames with eyes closed is greater than the threshold value, the count of the number of such frames starts.

If the number of frames in which the person closed their eyes exceeds 47, then an audible signal should be emitted.

The dlib library and a face detector based on a histogram of oriented gradients, as well as a predictor of facial features were used for the analysis.

When building the neural network, the time of day was also added, since the average person is most active in the first half of the day due to both homeostatic and circadian factors.

The general architecture of the Inception neural network is shown in Figure 6.

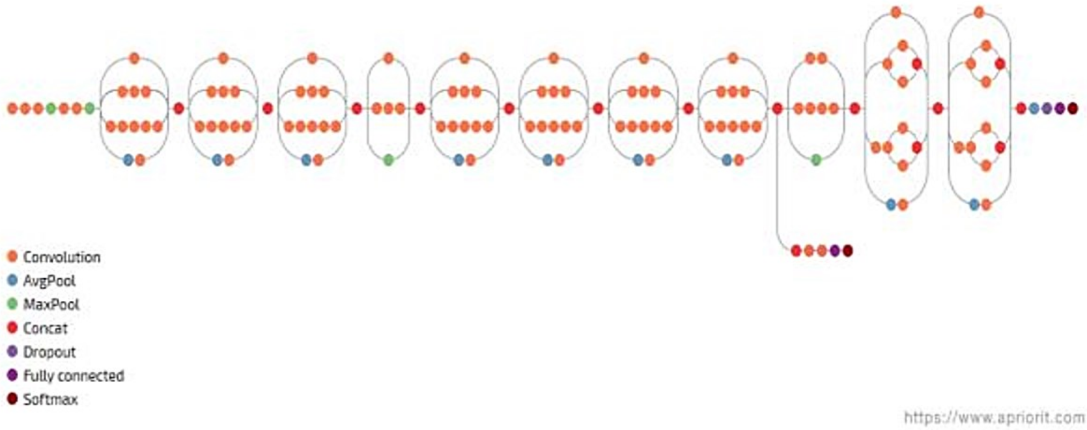


Figure 6. The architecture of the neural network

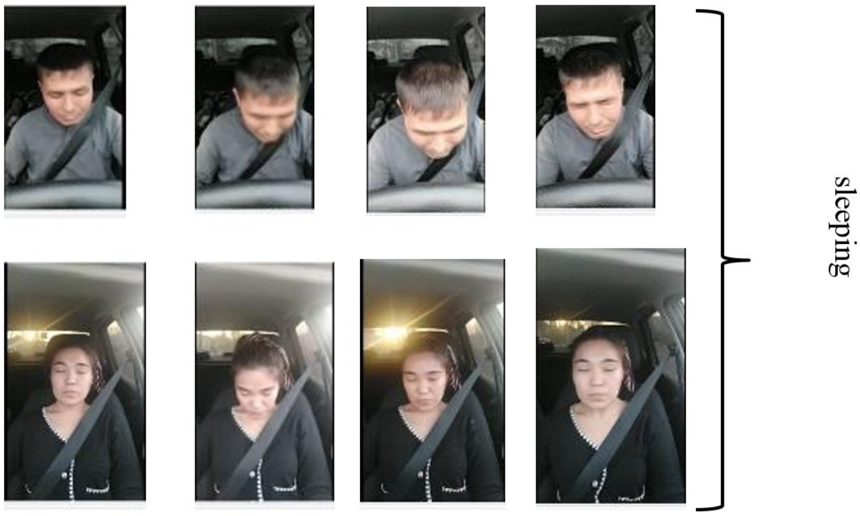
In this study, the developed neural network contains 3 layers:

- the first layer (input) - 7 elements;
- the second (hidden) layer - 14 elements;
- the third (output) layer - 2 elements.

The behavior of five drivers was analyzed: four men and one woman. Photos of the video sequence for training the neural network are shown in Figure 7a and 7b.

a

Figure 7. Photos from smartphone for neural network training



b

Figure 7. Photos from smartphone for neural network training

We use video using smartphones while driving. Smartphones of different manufacturers and models that belong to the test drivers were used for the purity of the experiment. A second experienced driver was in the car for insurance during dangerous driving in a state of fatigue. Also, a training ground in Semey was chosen for testing, where there is no busy traffic and random pedestrians, including children and people with disabilities.

Photos from the control sample are shown in Figure 8.

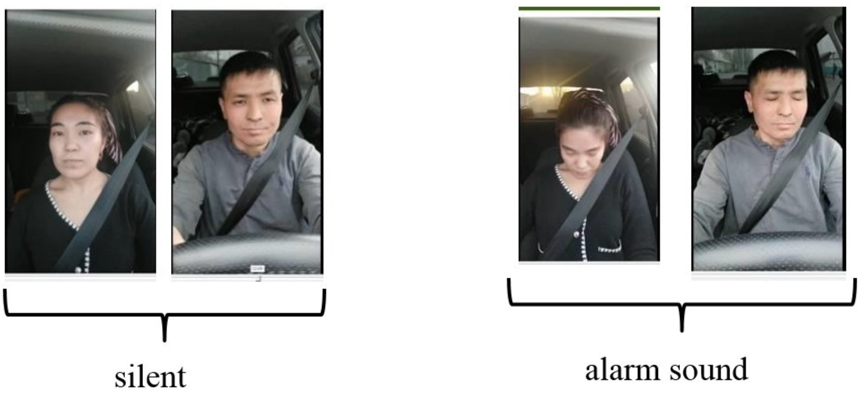


Figure 8. The control sample

In the course of experiments to detect driver drowsiness, results were obtained showing stable and sustainable operation of the application. The accuracy of the algorithm was 92%.

Results and discussion. As a result of the study, a software product was developed in the C # programming language, which allows you to determine the state of a driving person.

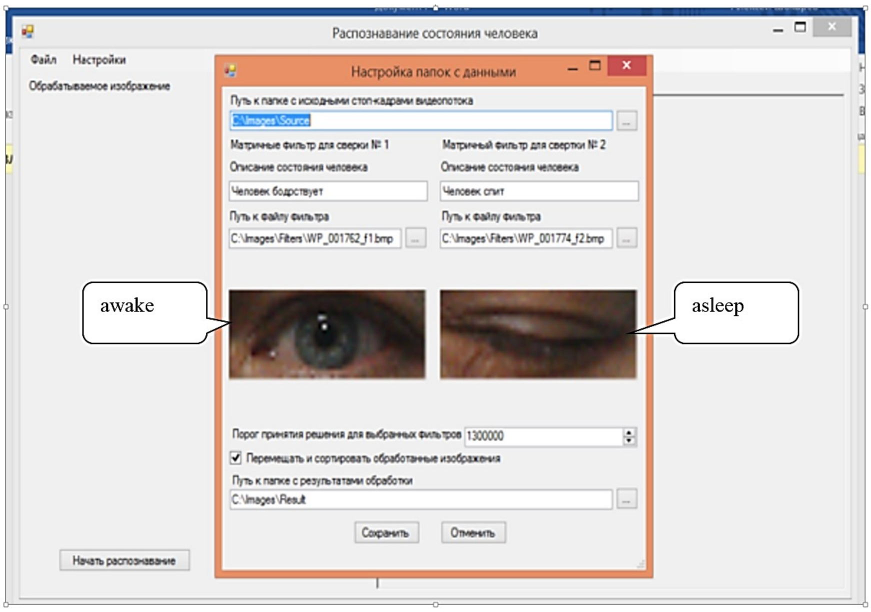


Figure 9. The main window of the software

The software product receives and processes signals from a smart bracelet and a smartphone video camera using a neural network and monitors the driver's condition in real time. If necessary, an audible signal is issued to attract the attention of the driver. The program allows to adjust the sensitivity of the algorithm for a specific driver, as well as the sound level for the alarm.

As noted above, the experiment was carried out under conditions close to real ones, at the training ground with the participation of drivers. According to the results of the experiment, we can assume the stable operation of the algorithm in natural conditions.

Further research will involve transferring the program from a computer to a smartphone. This will speed up the process of analyzing and processing information, as well as increase accuracy. Currently, the software product runs on the Windows operating system platform and requires a laptop or tablet in the car. Porting the program to the Android platform will allow drivers to use their smartphone without additional devices to run the application.

The software product received copyright certificate “A certificate on data registration in the state register of copyrighted objects of the Republic of Kazakhstan No. 18410, from June 04, 2021 (Shvets O, Shokarev A., Bakatbayeva Zh.)”.

Figure 10. A certificate on data registration in the state register of copyrighted objects of the Republic of Kazakhstan No. 18410, from June 04, 2021 (Shvets O, Shokarev A., Bakatbayeva Zh.)

Thus, the results obtained during the study showed the feasibility and relevance of using the developed algorithms based on neural network technology and a software product in real conditions to prevent drivers from falling asleep during driving.

Conclusions. It is presented ready-to-use software development of the method for processing EEG signals from a smart bracelet and a video sequence from a smartphone using neural network technology. All algorithms showed their efficiency in the course of full-scale experiments, the hypothesis was confirmed. Wi-Fi was used to transfer data from the smart bracelet and smartphone to the laptop. The developed software product differs from existing foreign analogues in its interface adapted to local conditions and relatively low cost. When transferring this software product to the Android platform, it can be used by drivers to control the state of fatigue or drowsiness, and when adapting the work of the program, it can be used in any routine monotonous work to monitor the state of the operator in front of the monitors.

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