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THE NEURAL NETWORK DEVELOPMENT AND TRAINING FOR RECOGNIZING THE STATE OF A DRIVER

Abstract. The topic of automated road safety support for all road users, the involvement of modern tools and advanced technologies to solve these problems is becoming more and more popular every year and does not lose its relevance. It was made a review of the currently existing works in this area, which showed the main advantages and disadvantages of the developments. It is noted the necessity to create a Kazakhstani automated system for monitoring the driver's condition, which will be available to the general public.

The purpose of this study is to develop a new model based on a neural network for recognizing the state of a person driving a car to identify a dangerous state of the driver. The paper deals with the following issues: the relevance of the study, the formalization of the recognition problem and the choice of neural network architecture, which most successfully solves the problem. Separate freeze frames extracted from the video sequence of observing the driver are used for a mathematical description of the problem, a recognition function is built to select three classes corresponding to the driver's state, and feature vectors are selected to correctly determine the condition.

For modeling, the architecture of a convolutional neural network was chosen, which allows working with images and video data streams.

As a result of the study, a neural network was built and trained to recognize the dangerous state of the driver, taking into account all the factors influencing the process of identifying such a state. The created neural network included two convolutional layers describing the position of the head and the degree of eye openness, and also added two fully connected layers to take into account additional parameters, such as time of a day, duration of the trip, and whether the driver is yawning. Evaluation of modeling accuracy and comparison of the new model with existing ones shows the novelty and practical significance of this work.

Keywords: neural networks, simulation, neural networks architecture, driver drowsiness, road safety.

Introduction.

The human factor is an important aspect of road safety throughout the world, which has been confirmed by studies over the past 50 years, for example [1, 2, 3].

The graph (see Fig.1) shows National Safety Council (NSC) data on the percentage of accidents due to driver fatigue or drowsiness for five European countries: Germany, Spain, Sweden, Italy and the United Kingdom for 2021 [4].

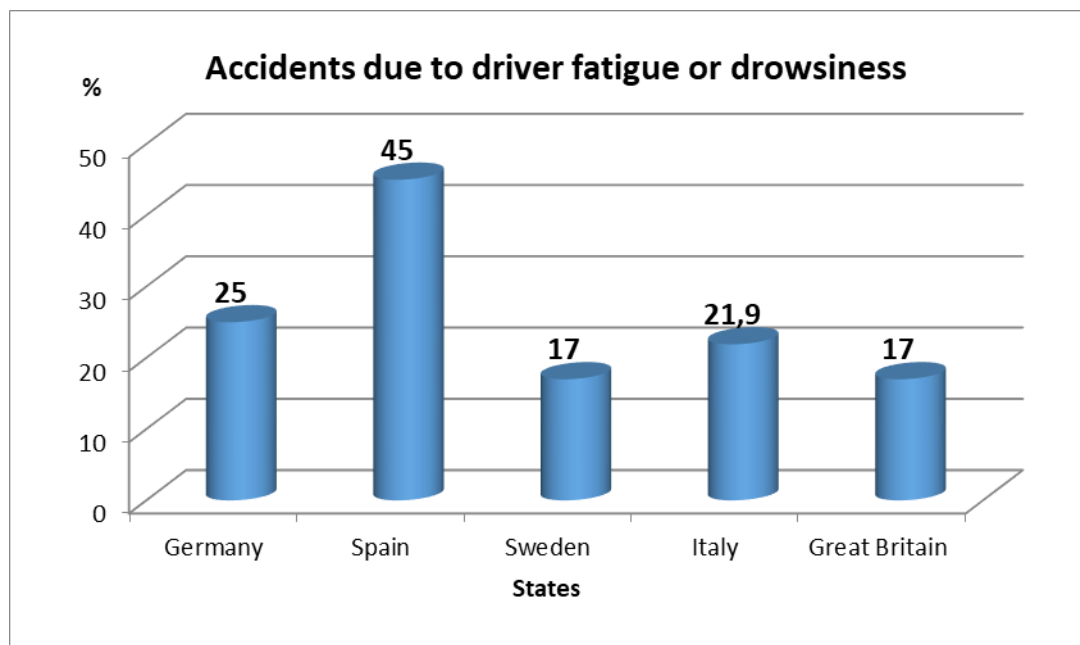


Figure 1 – Percentage of accidents due to driver fatigue or drowsiness

The second approach accumulates data about all the actions of the driver and the environment in the car: for example, using sensors and other devices, information about the car is collected, as well as data about the driver himself. In the event of an accident, all data before the accident is analyzed and compared with information in the event of accident-free driving. This approach reveals which factors increase the likelihood of an accident.

If we consider the market for automated driver support systems, it is possible to single out special equipment that comes with the car, i.e. built into its system, self-installed hardware purchased separately, and ready-made smartphone applications from Google Play or the App Store.

There are both undoubted advantages and disadvantages of these tools. The first drawback is the high price. Also, the driver's condition monitoring systems built into the car are stationary and do not allow them to be used in another car. Mobile applications cannot directly affect the driving process. Many people are unable to use some portable devices due to physical inconvenience because of devices in the form of bracelets or rings can interfere with driving.

It can be concluded from the foregoing, that today there is a necessity for a national Kazakh system for monitoring the condition of a car driver, which has a developed functionality for warning about a possible emergency, a relatively low cost and availability for the local population.

The purpose of the study is to develop a new model based on a neural network for recognizing the state of a driving person to identify a dangerous state of the driver.

Research hypothesis: the use of the latest advances in the field of modeling, automation and control will improve the accuracy of the system for monitoring the condition of a car driver. Hypothesis testing will be carried out by assessing the accuracy of the simulation and comparing it with existing analogues.

The subject of the study will be the identification of a dangerous state of the driver with the help of modern means of modeling, automation and control.

The research will be carried out in several stages: a review of trends in the development of driver monitoring systems, formalization and mathematical description of the task, justification for the choice of neural network architecture, creation and training of a neural network, analysis of the results.

Materials and methods.

At this moment, we have developed a part of an automated system for assessing the driver's condition as a part of a doctoral dissertation, a number of works have been published on this topic [6–9], where the issues of developing the system architecture and algorithms for processing images from a video stream are considered in detail. This study will describe the development of a new model based on neural network technologies, which is a continuation of the work on the dissertation.

There are many ready-made solutions for tracking the driver's condition on the market, from systems built into some modern car models to smart bracelets and mobile applications. A justification was given in the introduction to this article, and a conclusion was made about the need to develop a domestic analogue that is relatively inexpensive and accessible to ordinary people.

The development of driver control systems today goes in three directions, which are presented in Figure 2: driving style, brain activity and eye to eye.

Each direction has its own advantages, requires certain equipment and its implementation difficulties. All systems are usually equipped with a notification unit, which includes an alarm signal in sound, light or tactile form, and sometimes contains a combination of signals.

It should be noted that the architecture of the driver state assessment system consists of the following main blocks: capturing video from the camera, obtaining an input image, pre-processing, finding the face and eyes in the image, assessing the correctness of detection, assessing the opening / closing of the eyes, notification in case the driver is “sleeping”. A detailed description of this video stream processing algorithm is given in [6].

It follows from this that it is required to combine faces in images into non-overlapping classes in order to solve the recognition problem.

Let's formalize: it is necessary to build a recognition function

$$F(w) = (F_1(w), F_2(w), \dots, F_k(w)) \quad (1)$$

where

w – is an image class (output),

$x_1(w), \dots, x_n(w)$ – is a vector of features describing w .

In this case, the class is one of three possible driver states: sleeping, awake, or unknown. The formalized description will be represented by the formula:

$$F_k(w) = \begin{cases} 1, & \text{if } w \in k \\ 0, & \text{if } w \notin k \\ \Delta, & \text{if unclear } w \in k \text{ or } w \notin k \end{cases} \quad (2)$$

The search for a solution is carried out using artificial neural networks.

The central moments of the digital image of the face are determined by the formula:

$$m_{pq} = \sum_x \sum_y (x - \bar{x})^p (y - \bar{y})^q f(x, y) \quad (3)$$

where

\bar{x}, \bar{y} – values that are the center of gravity,

m_{pq} – central moments of order not higher than $(p+q)=3$,

$f(x, y)$ – brightness function.

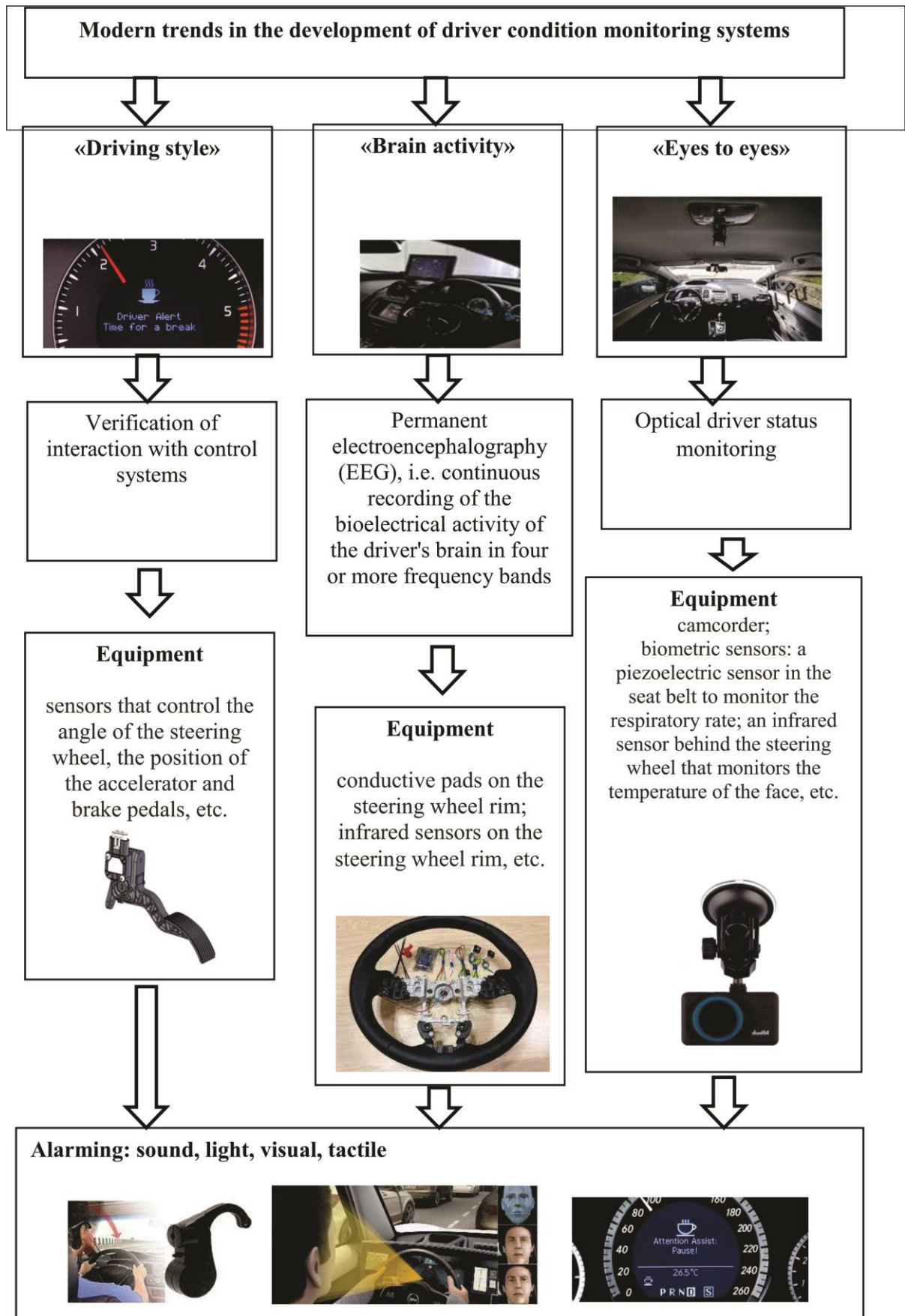
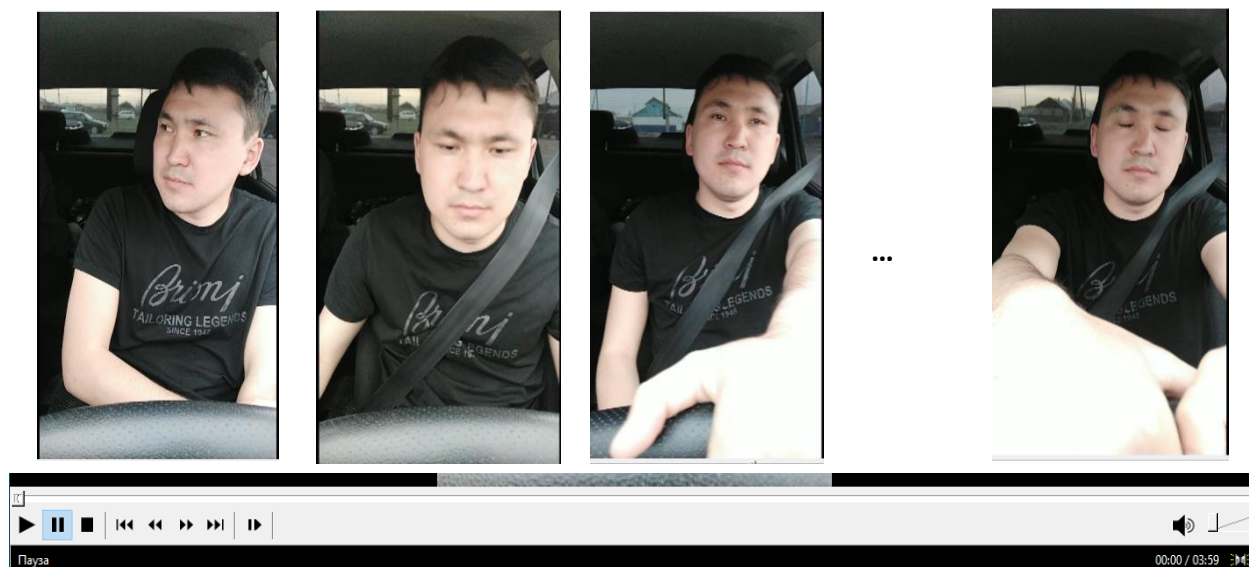


Figure 2 – Modern trends in the development of driver condition monitoring systems

The video data stream is a sequential set of frames.



The smartphone camera produces color images. It is advisable to convert color images to grayscale in order to improve the quality of processing. After the pre-processing step, the resulting image is a matrix of pixels, with each pixel having its own brightness value in the range [0, 1]. This algorithm is presented in detail in [7].

The neural network must attribute the received data set to one of the three driver states corresponding to a given set of parameters.

Thus, the mathematical description of the recognition problem will be as follows:

It is given:

M – a set of still frames $\{w_1, \dots, w_n\}$ of the video stream of monitoring the driver’s state, for example, “awake”,

$X_i = (x_{i1}, \dots), i=1, \dots, m, x_j \quad j = 1, \dots, n$ – a vector of feature values, where n is the number of features.

$\Omega_l, l = 1, \dots, k, M = \bigcup_{l=1}^k \Omega_l$ – some classes of feature vectors, and

$$\Omega_1 = \{w_1, \dots, w_{m_1}\},$$

$$\Omega_2 = \{w_{m_1+1}, \dots, w_{m_1+m_2}\},$$

$$\Omega_k = \{w_{m_k-1}, \dots, w_m\},$$

$$\sum_{l=1}^k m_l = |M|.$$

The entire sample was divided into two non-overlapping subsets: training and test to train the model. After training the artificial neural network on the training subset, the quality of its training on the test subset was checked.

To implement the task, it is sufficient to use an artificial neural network of direct propagation with a sigmoidal activation function and a linear activation function of the output layer.

Since the convolutional neural network is the best at processing images and video data, and the MatLab package has a powerful toolkit for designing networks with such architecture, we will use it. Figure 4 shows the developed architecture.

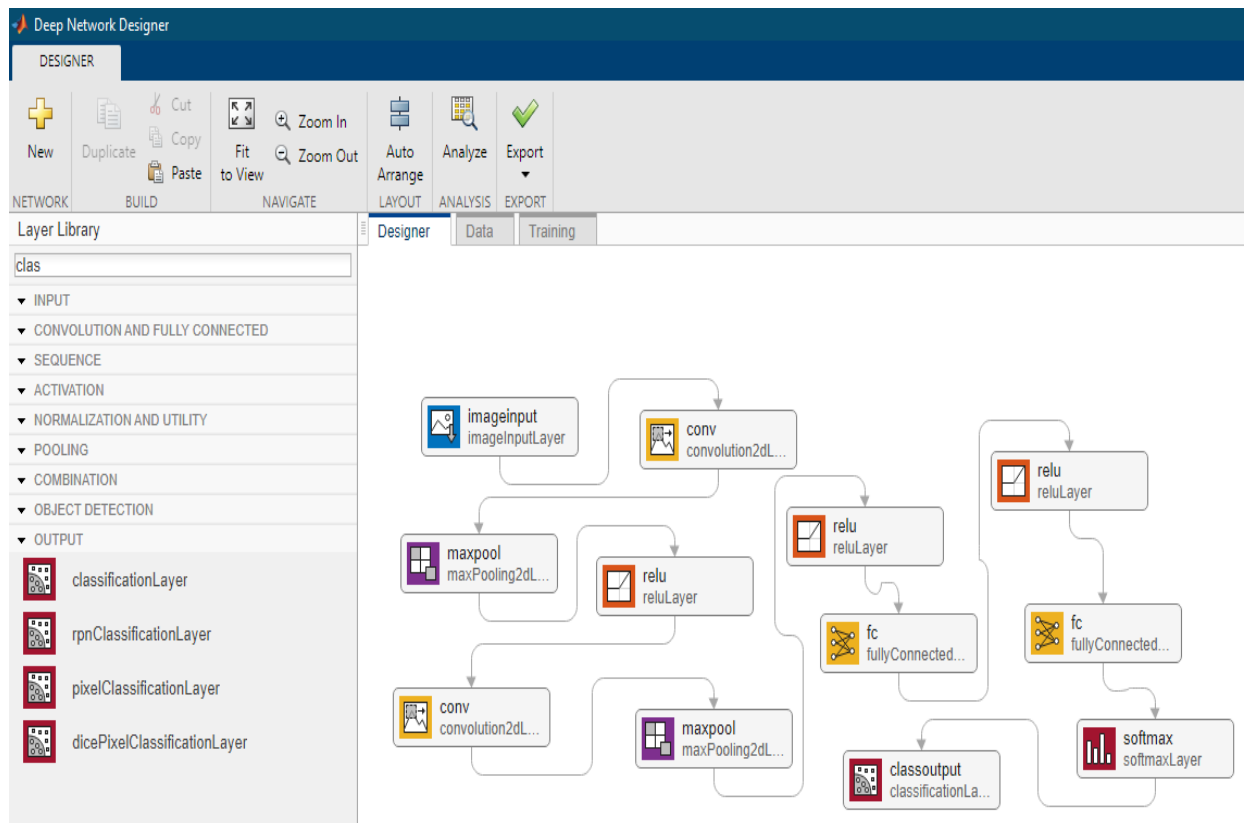


Figure 4 – Architecture CNN в Deep Network designer

Two convolutional layers (type: Convolution2D) were chosen to describe the degree of openness of the driver's eyes and the position of his head, as well as two fully connected layers (type: FullyConnected) to take into account additional parameters, such as travel time, time of day, and whether the driver is yawning. The element for describing the input data (ImageInput) allows you to specify the path to the folder with images from the camera of the driver's smartphone. The output layer (ClassOutput) contains the result of the neural network matching the incoming image to one of the three driver states.

Results and discussions.

Videos of five real drivers were used to train the neural network: four men and one woman. To create video streams in a state of driver fatigue, experimental staging trips on cars with insurance were carried out. There was a second driver in the cab to control the situation, and all trips with a tired driver took place at the Semey training ground.

The process of network training using the Neural Network training window is shown in Figure 5.

An Internet connection on a smartphone is required for use in real conditions for the correct operation of the application. Also, it is required to add a count of the number of frames with the “sleeping” state for the entire algorithm functioning. This is due to the human need to blink and trigger the algorithm only if there is a sequence of frames with the "asleep" state.

The hypothesis of the study was to use the latest advances in modeling, automation and control to improve the accuracy of the driver monitoring system.

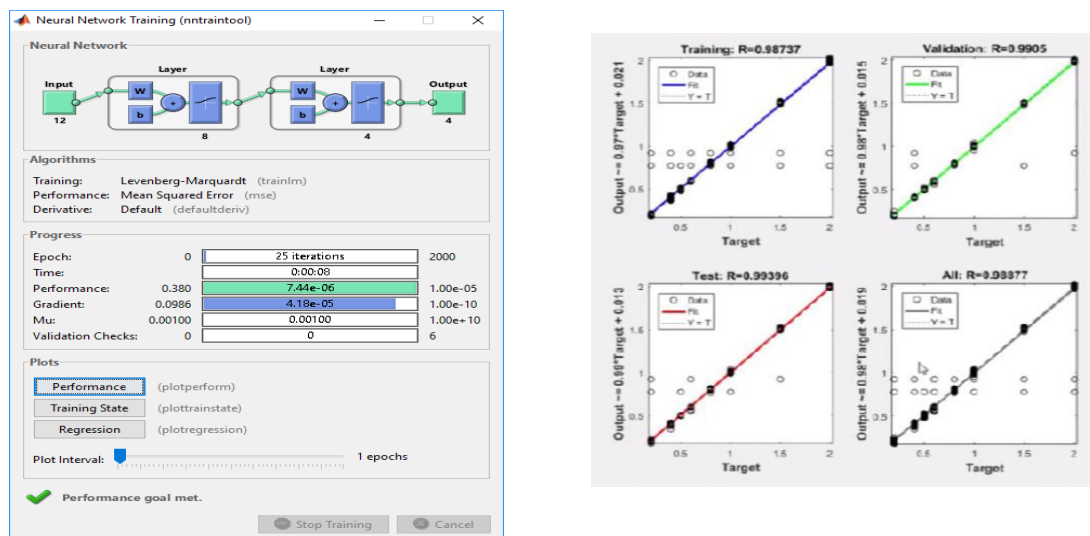


Figure 5 – Neural Network training

We will test the hypothesis by assessing the accuracy of the simulation and comparing it with existing analogues. The performance of existing monitoring systems was reviewed based on the reviews [10–12]. The simulation accuracy is approximately from 80% till 93%. The accuracy of our model is approximately 95%.

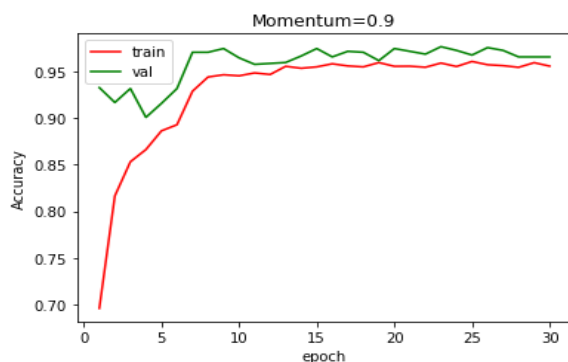


Figure 6 – Modeling Accuracy Assessment

As can be seen from Figure 6, the hypothesis was confirmed, the goal was achieved.

Conclusion.

The study showed that the use of the latest achievements in the field of modeling, automation and control for monitoring the state of the driver really improves the accuracy of the algorithm and thereby improves road safety. Modern modeling tools using neural networks allow solving complex and time-consuming tasks, reducing data processing time and improving the quality of automated tools.

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ЖҮРГІЗУШІНІҢ ЖАҒДАЙЫН ТАҢУ ҮШІН НЕЙРОНДЫҚ ЖЕЛІНІ ДАМУ ЖӘНЕ ОҚЫТУ

Аңдатпа. Барлық қозғалыс қатысушыларының автомобиль жолдарындағы қауіпсіздікті автоматтандырылған қолдау тақырыбы, осы міндеттерді шешу үшін

заманауи құралдар мен озық технологияларды тарту жыл сайын танымал болып келеді және өзектілігін жоғалтпайды. Өзірлемелердің негізгі артықшылықтары мен кемшіліктерін көрсеткен осы бағыт бойынша бүгінгі күні бар жұмыстарға шолу жасалды. Жүргізушінің жай-күйін мониторингілеудің қазақстандық автоматтандырылған жүйесін құру қажеттілігі атап өтілді, ол халықтың кең тобына қолжетімді болады.

Бұл зерттеудің мақсаты - жүргізушінің қауіпті жағдайын анықтау үшін рульдегі адамның жағдайын тану үшін нейрондық желіге негізделген жаңа модель жасау. Жұмыста зерттеудің өзектілігі, мәселені сәтті шешетін нейрондық желінің архитектурасын тану және таңдау мәселесін формализациялау мәселелері қарастырылады. Есепті математикалық сипаттау үшін жүргізушіні бақылау бейнесінен бөлінген жеке тоқтату кадрлары пайдаланылды, жүргізушінің күйіне сәйкес келетін үш сыныпты бөлектеу үшін тану функциясы құрылды және күйді дұрыс анықтау үшін ерекшелік векторлары бөлінді.

Модельдеу үшін суреттер мен бейне деректер ағынымен жұмыс істеуге мүмкіндік беретін конволюциялық нейрондық желі архитектурасы таңдалады.

Зерттеу нәтижесінде осындай жағдайды анықтау процесіне әсер ететін барлық факторларды ескере отырып, жүргізушінің қауіпті жағдайын тану үшін нейрондық желі құрылды және оқытылды. Құрылған нейрондық желіге бастың орналасуы мен көздің ашықтық дәрежесін сипаттайтын екі конволюциялық қабат енгізілді, сонымен қатар тәулік уақыты, сапардың ұзақтығы және жүргізушінің есінеуі сияқты қосымша параметрлерді есепке алу үшін екі толық байланысқан қабат қосылды. Модельдеу дәлдігін бағалау және жаңа модельді бар модельдермен салыстыру осы жұмыстың жаңалығы мен практикалық маңыздылығын көрсетеді.

Түйінді сөздер. Нейрондық желілер, модельдеу, нейрондық желі архитектурасы, жүргізушінің ұйқышылдығы, жол қауіпсіздігі.

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РАЗРАБОТКА И ОБУЧЕНИЕ НЕЙРОННОЙ СЕТИ ДЛЯ РАСПОЗНАВАНИЯ СОСТОЯНИЯ ВОДИТЕЛЯ

Аннотация. Тема автоматизированной поддержки безопасности на автомобильных дорогах всех участников движения, привлечение современных средств и передовых технологий для решения данных задач с каждым годом становится все более популярной и не теряет своей актуальности. Сделан обзор существующих на сегодняшний день работ по данному направлению, который показал основные достоинства и недостатки разработок. Отмечена необходимость в создании казахстанской автоматизированной системы мониторинга состояния водителя, которая будет доступна широким слоям населения.

Целью данного исследования является разработка новой модели на основе нейронной сети для распознавания состояния человека за рулем для выявления опасного

состояния водителя. В работе рассмотрены вопросы актуальности исследования, формализации задачи распознавания и выбора архитектуры нейронной сети, которая наиболее успешно решает поставленную проблему. Для математического описания задачи использованы отдельные стоп-кадры, выделенные из видеоряда наблюдения за водителем, построена распознающая функция для выделения трех классов, соответствующих состоянию водителя, и выделены векторы признаков для корректного определения состояния.

Для моделирования выбрана архитектура конволюционной нейронной сети, которая позволяет работать с изображениями и видеопотоком данных.

В результате исследования построена и обучена нейронная сеть для распознавания опасного состояния водителя с учетом всех факторов, влияющих на процесс выявления такого состояния. В созданную нейросеть были включены два конволюционных слоя, описывающие положение головы и степень открытости глаз, а также добавлены два полносвязных слоя для учета дополнительных параметров, таких как время суток, продолжительность поездки и наличие зевоты у водителя. Оценка точности моделирования и сравнение новой модели с существующими показывает новизну и практическую значимость данной работы.

Ключевые слова. Нейронные сети, моделирование, архитектура нейронных сетей, сонливость водителя, безопасность дорожного движения.
