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[1]Y. V. Melnyk,
[2]S. I. Otrokh,
[3]O. V. Sarafannikov,
[4]Y. V. Lebid

DRIVER BEHAVIOR RECOGNITION BASED ON NEURAL NETWORKS THEORY

[1]Faculty of Air Navigation, Electronics and Telecommunications, National Aviation University, Kyiv, Ukraine
[2,3,4]Department of Theoretical Electrical Engineering, National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute," Kyiv, Ukraine
E-mails: [1]melnik_yur@ukr.net, [2]2411197@ukr.net, [3]sarafan857@gmail.com, [4]yuriilebids@gmail.com

***Abstract*—*The article deals with the problem of driver behavior while driving the vehicle. Driver distraction can lead to serious accidents that threaten human life and public property around the world. Solving the problem of preventing dangerous driving behavior will reduce the risk of getting into an accident in the future. Thus, there is a need for a smart vehicle that will support driver behavior recognition functionality. A possible solution to the problem using an artificial neural network for automatic recognition of driver behavior on a real set of driver behavior data is considered. The high accuracy and efficiency of the developed model recognition is obtained.*

Index Terms—Driving behavior; artificial neural network; vehicle; safety index.

I. INTRODUCTION

Behavior and emotion recognition are important areas of human activity analysis that have attracted much attention from researchers in the field of pattern recognition and human behavior based on video or still images. In video-based behavior recognition, a sequence of images is used as input data and information about inter-frame motion is combined for feature classification [3]. Today, a large number of solutions to this problem are related to the processing of still images [6].

This problem can be solved by various traditional classification methods, such as linear SVM (Support Vector Machine), Softmax, naive Bayes, decision tree, Hidden Markov Model (HMM), Gaussian Mixture Model (GMM), random forest (RF), K-Nearest Neighbor (KNN) etc. These traditional methods are popular in building driving behavior models, there are some limitations such as using of expert experience to extract artificial features, the inability to take into account the time sequence and correlation in driving, the instability problem of higher dimensions such as large noise data, and limitation the structure of the model. This may cause the driving behavior recognition performance to be uneven and low in accuracy [2].

Recognition of driver behavior can be considered as a special case of human behavior recognition in general. However, there are some differences between recognizing human behavior in real life and driving. Recognition of driver behavior includes aspects [8]:

- all images are captured by a camera installed in the car. Thus, the stationary background does not allow providing global and semantic cues for behavior classification;
- the difference between driving styles manifests itself in small details, such as the steering wheel, hands, face, seat position.

II. PROBLEM STATEMENT

Road safety is a serious and relevant problem all over the world. The number of vehicles is growing rapidly, so this topic is becoming more and more important. Many road accidents are caused by the human factor, which naturally brings the problem of objectively assessing driver behavior during an accident investigation to the forefront.

Typical unsafe actions while driving, such as eating, using the phone, etc., can lead to serious consequences. Therefore, there is a need to develop intelligent functionality in the vehicle that will help recognize dangerous driving behavior. Such a real-time monitoring system will be able to provide accurate information on whether the driver's actions are authorized and, if necessary, give warning signals promptly.

Considering that the input data for such a monitoring system is the recognition of human driving behavior, which is the basis for drawing a conclusion about the safety situation, it is proposed to solve this problem using artificial neural networks. Artificial neural networks are the simplest simulation of the human brain and the building blocks are neurons. Multi-layered artificial neural networks also have neurons arranged in a similar way to the human brain [5].

III. PROBLEM SOLUTION

In order to solve this problem, a field experiment was conducted on the basis of the state farm distracted driver detection dataset to capture typical behaviors of drivers with little experience in driving vehicles. From the array of data obtained, experts selected 10 basic typical images, which were subsequently used to analyze and build an expert system based on an artificial neural network.

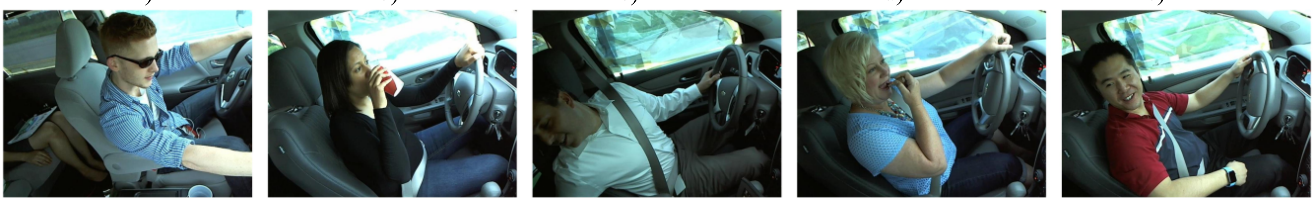
The dataset contains 22424 images which are divided into 10 classes (9 classes for different types of distraction driving activities and 1 class for safe driving) [1], each image size is 640×480 pixels (Fig. 1).

Before the image was fed into the classifier, each image was pre-processed. This step was performed to facilitate image processing by the neural network and further training on these images.

First, each image is converted into a multidimensional matrix 640×480×3, which is based on RGB values for each pixel, after which the matrix size changes to 64×64×3 to improve the efficiency of classifier calculations. At the end, the matrix is compacted to a vector that has a dimension of 12288 (Fig. 2). Each vector is assigned a numerical marking in the range from 0 to 9, depending on the class to which it belongs.

The data for training the system were divided into training and training sets in the proportion of (80×20)% respectively. Thus, the final training vector contains 17939 images and the validation vector contains 4485.

a) b) c) d) e)



f) g) h) i) j)

Fig. 2. Examples of images of driver behavior: a) safe driving, b) texting (right), c) talking on the phone (right), d) texting (left), e) talking on the phone (left), f) operating the radio, g) drinking, g) reaching behind, i) hair or makeup, j) talking to passenger

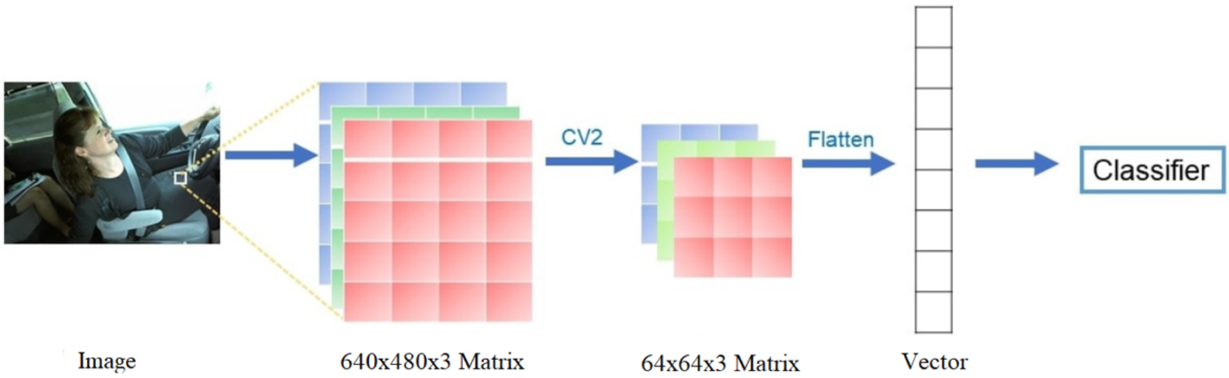


Fig. 3. Image preprocessing

The problem of image recognition and classification was solved on the basis of the constructed two-layer neural network. For this network [4]:

$$f(x;\theta)=\frac{1}{N}\sum_{i=1}^{N}\sigma_*(x;\theta_i), \tag{1}$$

where N is the number of hidden units (neurons); $\sigma_*:\mathbb{R}^d\times\mathbb{R}^D\to\mathbb{R}$, is the activation function; $\theta_i\in\mathbb{R}^D$ are parameters, which together are denoted as $\theta=(\theta_1,...,\theta_N)$.

In practice usually $\theta_i=(a_i,b_i,w_i)$, where a_i is the weight of unit i; b_i is the offset; $w_i\in\mathbb{R}^d$ is a vector of weighting coefficients, as well as

$$\sigma_*(x;\theta_i)=a_i\sigma(\langle w_i,x\rangle+b_i), \tag{2}$$

for some $\sigma:\mathbb{R}\to\mathbb{R}$. In this case $D=d+2$.

Experimentally, the value of N = 100 was chosen for the research problem.

$$\sigma(x)=\max\max(x,0), \tag{3}$$

$$\sigma(x_i)=\frac{e^{x_i}}{\sum_{j=1}^{K}e^{x_j}}, \tag{4}$$

where K is the number of behavior classes.

To solve this problem, we used the standard architecture of a two-layer neural network with activation functions for the hidden layer ReLU (3), and for the output layer softmax activation function (4).

The modeling of the system for monitoring and recognizing human behavior while driving was carried out in the PyCharm Community environment using an AMD Ryzen 7 5700U processor with Radeon Graphics.

As a result, the desired image classification is obtained according to each of the types of driving behavior provided by the system.

During the experiments, the two-layer neural network model showed an accuracy of 92.2%. For a more detailed analysis, it is advisable to analyze the accuracy for each class of driving behavior. The accuracy of the model for each of the classes is shown in Table I.

Driver behavior is one of many key factors that must be considered to improve road safety. The main difficulty in determining behavior was the lack of a single standard method for modeling it. The driver safety index (SI) was used to recognize the driver's behavior while driving a vehicle [7].

$$\mathrm{SI}=\{n_1\beta_1+n_2\beta_2+...+n_9\beta_9\}, \tag{5}$$

where $n_{1...9}$ is the number of each distraction behavior class; $\beta_{1...9}$ is the weight of each distraction behavior class.

Assigned to each distraction behavior class $\beta=0.11$.

TABLE I. ACCURACY OF THE MODEL BY CLASS

Behavior class	Accuracy, %
Safe driving	89.2
Texting (right)	97.8
Talking on the phone (right)	95.83
Texting (left)	98.37
Talking on the phone (left)	71.24
Operation the radio	98.28
Drinking	98.03
Reaching behind	97.08
Hair or makeup	78.97
Talking to passenger	96.2

For the system of monitoring and recognizing human behavior while driving, 4 types of behavior are defined: highly safe, safe, distracting, and highly distracting. The safety indices for each behavior are shown in Table II.

TABLE II. SAFETY INDEXES FOR DIFFERENT TYPES OF BEHAVIOR

Type of behavior	Safety index (SI)
Highly safe	0.9 – 1
Safe	0.7 – 0.89
Distracting	0.5 – 0.69
Highly distracting	< 0.5

That is, the higher the index, the fewer distractions were made during the trip and the safer the driver's behavior.

IV. CONCLUSIONS

The problem of distracted driver behavior while driving a vehicle is considered. A solution to the problem of recognizing driver behavior using an artificial neural network is proposed. The constructed neural network showed an accuracy of 92.2%. As for certain classes of driver behavior, the accuracy rates are quite high. However, the classes “Talking on the phone (left)” and “Fixing hair or make-up” have significantly lower accuracy (see Table I). For phone conversations when the phone is in the left hand, the relatively low accuracy can be explained by the fact that it can be similar to using the phone in the left hand. And make-up and fixing hair by gestures is similar to drinking. A safety index was also introduced to classify the type of driver.

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Melnyk Yurii. Doctor of Engineering Science. Professor.
Faculty of Air Navigation, Electronics and Telecommunications, National Aviation University, Kyiv, Ukraine.
Education: Kyiv Military Aviation Engineering Academy, Kyiv, Ukraine, (1986).
Research area: ergonomic systems, intelligent control systems.
Publications: 75.
E-mail: melnik_yur@ukr.net

Otrokh Serhii. Doctor of Engineering Science. Professor.
Educational and Research Institute of Nuclear and Heat Power Engineering, National Technical University of Ukraine "Ihor Sikorsky Kyiv Polytechnic Institute," Kyiv, Ukraine.
Education: Kyiv Institute of Telecommunications at the Ukrainian State Academy of Telecommunications, Kyiv, Ukraine, (1999).
Research area: neural networks, artificial intelligence, networks of the future.
Publications: 86.
E-mail: 2411197@ukr.net

Sarafannikov Oleksandr. ORCID 0000-0002-8373-4629. Student.
Educational and Research Institute of Nuclear and Heat Power Engineering, National Technical University of Ukraine "Ihor Sikorsky Kyiv Polytechnic Institute," Kyiv, Ukraine.
Education: National Technical University of Ukraine "Ihor Sikorsky Kyiv Polytechnic Institute," Kyiv, Ukraine.
Research area: neural networks, artificial intelligence, networks of the future.
Publications: 5.
E-mail: sarafan857@gmail.com

Lebid Yurii. ORCID 0009-0004-5312-9892. Student.
Educational and Research Institute of Nuclear and Heat Power Engineering, National Technical University of Ukraine "Ihor Sikorsky Kyiv Polytechnic Institute," Kyiv, Ukraine.
Education: National Technical University of Ukraine "Ihor Sikorsky Kyiv Polytechnic Institute," Kyiv, Ukraine.
Research area: neural networks, artificial intelligence, networks of the future.
E-mail: yuriilebids@gmail.com

Ю. В. Мельник, С. І. Отрох, О. В. Сарафанніков, Ю. В. Лебідь. Розпізнавання поведінки водія на основі теорії нейронних мереж

У статті розглянуто проблему поведінки водія за кермом. Відволікання водія може призвести до серйозних аварій, що загрожують життю людей та громадському майну у всьому світі. Вирішення проблеми попередження небезпечної поведінки водія за кермом дозволить зменшити ризики потрапляння у дорожньо-транспортні пригоди в майбутньому. Таким чином, є потреба у розумному транспортному засобі, який буде підтримувати функціонал з розпізнавання поведінки водія. Розглянуто можливий варіант вирішення проблеми з

використанням штучної нейронної мережі для автоматичного розпізнавання поведінки водія на реальному наборі даних поведінки водія. Отримано високу точність та ефективність розпізнавання розробленої моделі.
Ключові слова: поведінка водія за кермом; штучні нейронні мережі; транспортний засіб; індекс безпеки.

Мельник Юрій Віталійович. Доктор технічних наук. Професор.
Факультет аеронавігації, електроніки та телекомунікацій, Національний авіаційний університет, Київ, Україна.
Освіта: Київське вище військове авіаційне інженерне училище, Київ, Україна, (1986).
Напрям наукової діяльності: ергатичні системи, інтелектуальні системи управління.
Кількість публікацій: 75.
E-mail: melnik_yur@ukr.net

Отрох Сергій Іванович. Доктор технічних наук. Професор.
Навчально-науковий інститут атомної та теплової енергетики, Національний технічний університет України «Київський політехнічний інститут ім. Ігоря Сікорського», Київ, Україна.
Освіта: Київський інститут зв'язку Української державної академії зв'язку ім. О.С. Попова, Київ, Україна, (1999).
Напрям наукової діяльності: нейронні мережі, штучний інтелект, мережі майбутнього.
Кількість публікацій: 86.
E-mail: 2411197@ukr.net

Сарафанніков Олександр Вікторович. ORCID 0000-0002-8373-4629. Студент.
Навчально-науковий інститут атомної та теплової енергетики, Національний технічний університет України «Київський політехнічний інститут ім. Ігоря Сікорського», Київ, Україна.
Освіта: Національний технічний університет України «Київський політехнічний інститут ім. Ігоря Сікорського», Київ, Україна.
Напрям наукової діяльності: нейронні мережі, штучний інтелект, мережі майбутнього.
Кількість публікацій: 5.
E-mail: sarafan857@gmail.com

Лебідь Юрій Володимирович. ORCID 0009-0004-5312-9892. Студент.
Навчально-науковий інститут атомної та теплової енергетики, Національний технічний університет України «Київський політехнічний інститут ім. Ігоря Сікорського», Київ, Україна.
Освіта: Національний технічний університет України «Київський політехнічний інститут ім. Ігоря Сікорського», Київ, Україна.
Напрям наукової діяльності: нейронні мережі, штучний інтелект, мережі майбутнього.
E-mail: yuriilebids@gmail.com