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INTELLIGENT SYSTEM FOR NOTIFYING THE DRIVER OF DISTRACTIONS FROM DRIVING THE VEHICLE

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Abstract—The article discusses the development of a functional system that, based on the recognition of distracting behaviour by the driver, is capable of issuing warning signals that the driver is distracted from the process of driving a vehicle. The described methodology covers basic methods and procedures necessary for the creation of a precision, resistant to disturbances, and at the same time controllable system for precision stabilization of the equipment assigned for operation on moving vehicles of a wide class. As part of the study, such a system was developed that takes into account the driver's reaction time, age, gender, and duration of the trip. If a critical situation is detected, the system automatically generates a warning signal for the driver. The features of the modern approach to data processing based on neural networks are described. The implementation of such a system is aimed at improving road safety and reducing the number of accidents. The developed emergency warning system not only allows drivers to mitigate the consequences of road accidents, but also helps them to avoid them by drawing their attention to emerging dangers in a timely manner if the driver's response is insufficient or absent.

Keywords—Driving behavior, computer vision, behaviour classification, accident prevention, intelligent transport systems, ADAS.

I. INTRODUCTION

An analysis of global experience in the creation and application of intelligent transport systems has shown that, in order to increase their effectiveness, it is necessary to optimise the processes of interaction between the system and the driver, who is the final decision-maker when it comes to controlling the vehicle and choosing the route [2], [7].

According to the GHSA (Governors Highway Safety Association), 25% of all accidents occur because the driver's attention is distracted by secondary tasks unrelated to driving [8], [15]. According to social surveys, 33% of respondents said they read messages, emails or news on their mobile phones, 25% write messages or emails, and 70% talk on their mobile phones [5], [9]. This suggests that a legislative ban is not a sufficiently effective way to solve the problem in this case.

As a solution to this problem, the scientific community proposed an approach to developing active safety systems aimed at preventing accidents based on monitoring the behaviour of the vehicle driver and timely alerting the driver to the current situation by generating context-oriented recommendations. Monitoring dangerous behaviour [13], [4] behind the wheel can help draw the driver's attention to their driving style and the associated

risks, thereby reducing the percentage of careless driving and improving safe behaviour on the road.

II. THE AIM AND OBJECTIVE

The aim of this study is to develop a functional system capable of recognising distracting behaviour in drivers and generating warning signals when drivers are not paying attention to the driving process. To achieve this goal, it is necessary to analyse the factors that influence driver distraction, develop an algorithm that takes into account reaction time, age, gender and trip duration, develop an automated warning mechanism that is activated in critical situations, and evaluate the effectiveness of the proposed system in improving road safety and reducing the number of road accidents.

III. EXISTING SOLUTIONS TO THE PROBLEM

Driver behavior recognition is a difficult task due to the inherent complexity and variability of human behavior. In recent years, there has been growing interest in using artificial intelligence methods, particularly neural networks, for driver behavior recognition. Research in this area has a relatively short history. Over the past decade, several algorithms have been proposed to address the problem of recognizing driving behavior.

The most common approach involves using cameras and computer vision algorithms to analyze driver behavior. Such systems make it possible to track head position, gaze direction, etc. One of the major areas of focus is the use of convolutional neural networks (CNNs). K. Alshafan and M. Zakariah proposed a CNN architecture based on VGG-16 for classifying driver distractions [1]. H. Eraqi et al. used a CNN ensemble, which integrates outputs from several CNN architectures and improves the accuracy of recognizing different types of distractions and enables real-time operation [6].

The current trends in scientific research focus on the development of multimodal systems that combine various data sources, such as visual information, physiological signals, and environmental context. Such systems are designed to ensure a more comprehensive understanding of the driver's condition. For instance, modern approaches integrate driver monitoring with traffic situation analysis using object detection models such as YOLO and Faster R-CNN. These models enable real-time detection of surrounding objects (vehicles, pedestrians, road signs), which can be combined with driver behavior analysis to enhance the overall reliability of the system [12].

At the same time, many existing solutions are evaluated under controlled conditions and may not always perform well in real-world conditions. Furthermore, high computational requirements and dependency on specialized hardware remain the main obstacles to their widespread adoption [10].

IV. PROBLEM STATEMENT

Road traffic accidents cause significant socio-economic damage, affecting the health and lives of people around the world. In recent years, the damage caused by road traffic accidents has exceeded the damage caused by all other transport accidents (aircraft, ships, trains, etc.) combined [2]. Road traffic accidents are one of the most serious threats to human health and life worldwide. The problem is exacerbated by the fact that those injured in accidents are usually young and healthy (before the accident) people. According to the World Health Organisation [14], [11], approximately 1.25 million people die and up to 50 million suffer non-fatal injuries in road traffic accidents worldwide each year [2].

Today, almost every new car delivered from the manufacturer's factory is equipped to some extent with passive (e.g., seat belts, airbags, etc.) and active (e.g., anti-lock braking system, stability control system, lane departure warning system, etc.) safety features [15]. While passive safety systems are

activated after a road traffic accident has occurred, active safety systems are activated in advance and attempt to prevent or avoid a collision. Our research will focus on active safety systems.

ADAS is a class of systems that exist in the form of hardware and software complexes (cameras, sensors, chips, etc.) and are designed to assist drivers in preventing accidents or mitigating their consequences. These systems are installed in vehicles primarily at car manufacturers' plants. These systems emit high-priority warning signals to stimulate driver alertness and prompt timely and appropriate action in situations where there is a risk or immediate danger of serious injury or death. Technologies that make up ADAS systems include lane departure warning systems, speed limit warning systems, and blind spot monitoring systems. Despite the variety of integrated ADAS solutions on the automotive market and their high quality and speed of operation, there are significant drawbacks to integrated ADAS systems: the cost of such systems remains quite high; they are mainly available only as an additional option for expensive and exclusive cars.

When the driver's concentration decreases, the characteristics of involuntary deviations change, as the driver pays less attention to monitoring the traffic environment. The main condition in which the driver's concentration decreases is when their attention is diverted to secondary tasks not related to the process of driving [7], [14].

Drivers may be distracted by certain events, actions, objects, or people inside or outside the vehicle. Distraction can be characterized as any activity (visual, auditory, motor, mental) that diverts the driver's attention from driving tasks. However, the greatest danger is posed by distraction caused by secondary tasks unrelated to driving, which divert the driver's attention from the road for a long time.

Distraction can only be determined within a short time interval when a secondary task is being performed. Secondary tasks vary in complexity or the degree to which they involve the driver.

V. MATHEMATICAL MODELLING

Among the distracting behaviours of drivers behind the wheel, the main dangerous types of secondary tasks that significantly increase the risk of getting into dangerous situations can be identified [5]: reaching for an unsecured object – risk equal to 8.8, looking at an external object (staring) – 3.7, reading – 3.38, applying makeup – 3.13, pressing buttons on a handheld device – 2.79. More detailed results are presented in Table I.

The analysis of possible risks is given in Table I.

Distraction can only be determined within a short period of time, lasting a few seconds, during which it must be monitored whether the driver is looking at the road or not and/or performing any secondary tasks (e.g., navigating complex information systems, using a mobile phone, etc.) [13]. The more complex and prolonged the secondary tasks are, the greater the level of distraction.

TABLE I. PROBABILITY OF RISK OF ENCOUNTERING A DANGEROUS SITUATION WHILE THE DRIVER IS PERFORMING SECONDARY TASKS NOT RELATED TO DRIVING

Type of secondary task	Probability of risk (from 0 to 10)	Lower confidence interval, s	Upper confidence interval, s
Reaching for an uncaptured object	8.82	2.50	31.16
Looking at an object outside the car	3.70	1.13	12.18
Reading	3.38	1.74	6.54
Applying makeup	3.13	1.25	7.87
Pressing buttons on a phone	2.79	1.60	4.87
Eating	1.57	0.92	2.67
Moving objects	1.38	0.75	2.56
Talking on a headset	1.29	0.93	1.80
Drinking from a bottle	1.03	0.33	3.28
Tuning the radio	0.55	0.13	2.22
Talking to a passenger in the front seat	0.50	0.35	0.70
Talking to a passenger in the back seat	0.39	0.10	1.60
Brushing hair	0.37	0.05	2.65

The driver's behaviour and actions while driving are the main profile information used to monitor their behaviour in the vehicle cabin for the presence of a particular hazardous condition. The driver's behaviour while driving a vehicle is characterised by the occurrence of dangerous situations recognised at a certain point in time, the combination of which allows the system to decide whether or not there has been potentially dangerous behaviour over a certain period of time.

Each frame received from the smartphone camera allows the driver's characteristics to be read and recognised for further analysis of the possible dangerous situation in which he finds himself at a given moment in time. Digital image processing and

analysis for driver behaviour characteristics involves numerous operations, many of which require a certain amount of time, which can affect the quality and speed of the system as a whole.

Initial image pre-processing is used as an optimisation method to increase the FPS (frames per second) rate. This involves proportional scaling (reduction) of the image resolution and subsequent conversion of all image pixels to a grey scale palette. The image is converted to a 256-shade greyscale mode as follows:

$$Y = 0.299R + 0.587G + 0.114B, \quad (1)$$

where R, G, B are intensities ranging from 0 to 255, Y is the intensity for each channel of the new pixel colour.

Each frame is used to evaluate the driver's behaviour in order to analyse potentially dangerous situations in which they may find themselves at any given moment. OpenCV framework and computer vision algorithms are used to search for and locate the driver's body (body posture, specific actions while driving).

When a dangerous situation arises on the road, it is important to make quick decisions to avoid an accident. An important parameter is the driver's reaction time, which characterises the moment when a dangerous situation is detected until the driver takes action. This indicator is individual for each driver and time [3].

One of the key parameters for assessing the danger of a driver's behaviour is the number of dangerous situations within a given time interval. This parameter depends on the time taken to process dangerous situations and the driver's reaction time [3]. Based on research in the field of driver reaction time analysis, the following formula is proposed for determining the number of dangerous situations:

$$n = 1 + \left(2 \frac{E}{t_{\text{reaction}} + 0.5} \right)^2, \quad (2)$$

where E is smartphone computing power coefficient; t_{reaction} is driver reaction time in seconds.

Thus, with a decrease (increase) in the processing time for a single dangerous situation or a decrease (increase) in the driver's reaction time, the parameter n increases (decreases), thereby allowing for more accurate recognition of dangerous conditions in the driver's behaviour, taking into account a greater number of potential dangerous situations within the allotted time and, conversely, increasing the probability of missing or falsely triggering the

detection of a particular dangerous condition, which affects the further operation of the module that generates recommendations to the driver.

The average reaction time of a driver to a dangerous situation depends not only on the individual characteristics of the driver, their gender and age, but also on the current time of day and the speed of the vehicle [1], [9]. In accordance with the parameters listed, it has been proposed that the average time be determined as follows:

$$t_{reaction} = \frac{A\omega_1 + G\omega_2 + DT\omega_3}{V\omega_0}, \quad (3),$$

where A is the driver's age; G is the driver's gender (male / female); DT is travel time in minutes; V is smartphone computing power coefficient; $\omega_0, \omega_1, \omega_2, \omega_3$ are weighting coefficients for each of the listed parameters.

The dependence of the number of dangerous situations on the driver's reaction time and the computing power of the smartphone is shown in Fig. 1.

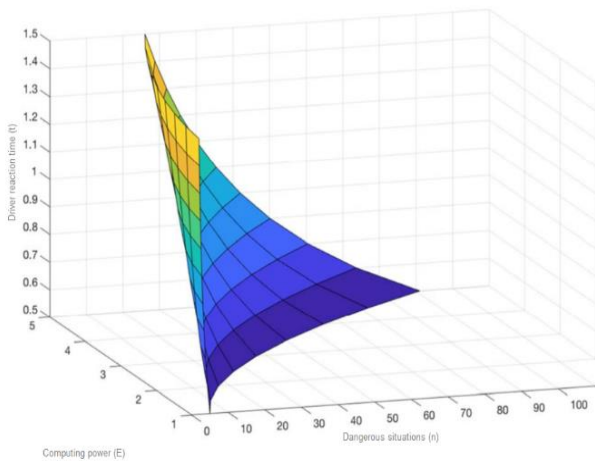


Fig. 1. The dependence of the number of dangerous on the driver's reaction time and smartphone productivity

When the driver's reaction deteriorates or the smartphone's computing resources are limited, the number of frames of the driver's body processed from the smartphone camera image decreases, and conversely.

Each dangerous situation in the driver's behaviour corresponds to a set of recommendations for preventing an accident. As a priority measure to prevent accidents, the driver must pay attention to the system's warnings and avoid distractions while driving. Outgoing warning notifications generated by a smartphone about potentially dangerous behaviour can be generated to the driver in the following ways:

- voice notification (speech synthesis based on printed text) using the smartphone's speakers;
- audible signal using the smartphone's speakers.

When signs of distraction from driving are detected, the system will warn the driver with an audible signal, thereby attracting their attention. If dangerous actions behind the wheel are repeated, the system will prompt the driver to stop.

The general scheme of the system for recognising driver behaviour and providing them with audible signals is shown in Fig. 2.

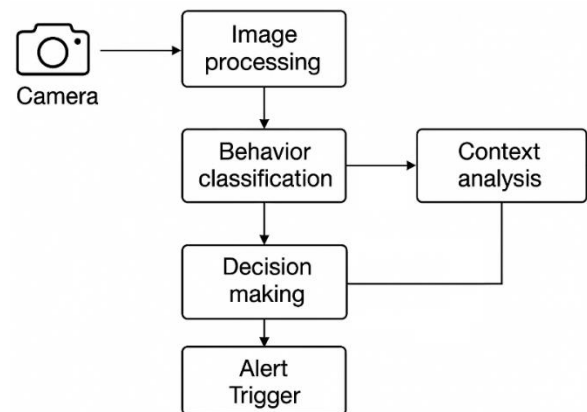


Fig. 2. The dependence of the number of dangerous situations on the driver's reaction time and smartphone productivity

The operation of the driver behaviour recognition system for detecting distractions behind the wheel and sending warning signals to the driver can be described in several stages. First, the camera captures a video stream, which is transmitted to the frame collection module, where the continuous video signal is converted into a discrete sequence of frames. The image pre-processing module normalises the frames, resizes them, and highlights key areas of the driver's body. The resulting data passes through a neural network that determines the type of distracting behaviour. The classification result is transmitted to the decision-making module, where, if the risk threshold is exceeded, the system issues an audible warning about distraction from driving.

VI. CONCLUSIONS

The developed emergency warning system not only allows drivers to mitigate the consequences of road accidents, but also helps them to avoid them by drawing their attention to emerging dangers in a timely manner if the driver's response is insufficient or absent. This is possible thanks to the generation

of appropriate warning signals and recommendations.

The results of this work can be valuable for the automation and modeling of NSC processes using information technologies, including the development of digital twins of the NSC for process management and personnel training purposes

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С. І. Отрох, О. В. Сарафанніков, Ю. В. Мельник. Інтелектуальна система сповіщення водія про фактори відволікаючі від керування транспортним засобом

У статті розглядається розробка функціональної системи, яка на основі розпізнавання відволікаючої поведінки водія здатна видавати попереджувальні сигнали про те, що водій відволікається від процесу керування транспортним засобом. Описана методологія охоплює основні методи та процедури, необхідні для створення прецизійної, стійкої до збурень та водночас керованої системи прецизійної стабілізації обладнання, призначеного для експлуатації на рухомих транспортних засобах широкого класу. В рамках дослідження була розроблена така система, яка враховує час реакції водія, вік, стать та тривалість поїздки. У разі виявлення критичної ситуації система автоматично генерує попереджувальний сигнал для водія. Описано особливості сучасного підходу до обробки даних на основі нейронних мереж. Впровадження такої системи спрямоване на підвищення безпеки дорожнього руху та зменшення кількості аварій. Розроблена система екстреного попередження не тільки дозволяє водіям пом'якшити наслідки дорожньо-транспортних пригод, але й допомагає їм уникнути їх, своєчасно звертаючи їхню увагу на небезпеки, що виникають, якщо реакція водія недостатня або відсутня.

Ключові слова: поведінка водія, комп'ютерний зір, класифікація поведінки, запобігання аваріям, інтелектуальні транспортні системи, ADAS.

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