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DRIVER BEHAVIOR MONITORING SYSTEM

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This paper considers the system of monitoring a driver behind the wheel of a car. The main goal is to implement a system using methods of object detection and monitoring in the video data stream, which will work in real-time and will use low computing power and low power consumption for data processing. The system model consists of two parts: the selection of eye landmarks and the use of the Naive Bayes classifier to determine the driver's behavior on signs of fatigue, falling asleep, and distraction while driving.

Keywords: object recognition, face landmarks, eye aspect ratio (EAR), Naive Bayes classifier, data security.

Introduction

Every day the car development progress is growing. There are even cars that have an automatic control system, provided that the road meets the standards. In addition, systems are being developed that monitor the road and notify a driver in case of danger. However, all modern road tracking technologies are available only in new cars that appear on the market.

Also, every day the number of car accidents increases due to drowsiness of a driver or his distraction while driving. According to statistics, the less a driver sleeps, the greater the risk of an accident. According to researchers, severe sleep deprivation reduces attention and concentration as well as alcohol.

The figures are really impressive: if a person slept for 6 hours - the risk of an accident increases 1.3 times; 5-6 hours – almost twice; 4-5 hours – 4.3 times. And if the driver slept less than 4 hours a night before the trip - the probability of an accident increases by 11.5 times.

In 2005, American researchers conducted a study by the National Sleep Foundation, according to which about 168 million adults (60% of all motorists) got behind the wheel sleepy, and a third of them fell asleep while driving. At the same time, for 13% of them this situation occurs regularly, and about 11 million drivers were involved in accidents due to fatigue and lack of concentration [7].

This paper considers the approach to solving this problem based on the observation of a driver's behavior while driving.

Each car has a rearview mirror. The idea is to replace this mirror with a smart mirror, which will monitor a driver's behavior through video surveillance and report it in case of danger in the form of audio messages. In addition, the mirror will be able to interact with the car's multimedia, which will give access to the car's audio output. Of course, these are only the initial capabilities of the prototype, which will be developed in the process of research and implementation. The main condition is that the data processing must be performed in real-time, and the monitoring model will run on a low-power microcomputer.

Model overview and experiments

Since the monitoring model will run on a low-power microcomputer, the model should have simple and fast data processing techniques.

The model consists of eye landmark recognition, eye closing and blinking monitoring, and inattention monitoring (fig. 1).

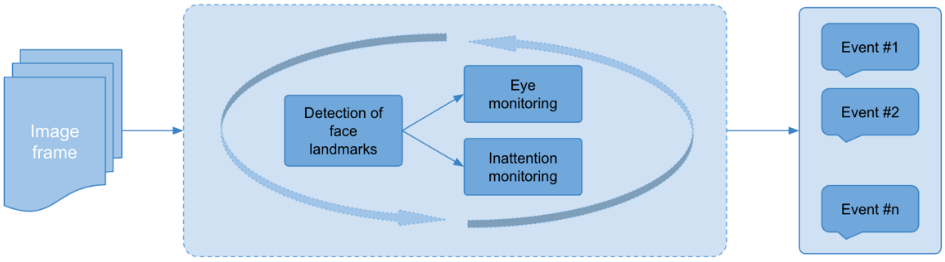

Fig. 1. Driver monitoring system architecture

In real-time, the system takes an image frame from the video stream and performs facial landmark recognition. The modified Histogram of Oriented Gradients method in combination with the Linear SVM method is used to recognize the landmarks of facial elements [1, 9]. This method of facial landmark recognition is implemented in the Dlib library. Dlib is a modern C++ toolkit containing machine learning algorithms and tools for creating complex software in C++ to solve real world problems [2]. Dlib's open source licensing allows you to use it in any application, free of charge.

The face landmark detector, implemented in the dlib library, returns 68 (x, y) coordinates that reflect specific facial structures. The detector model is trained in the iBUG 300-W dataset [3], this model can be retrained if necessary.

The face landmark detector data (fig. 2):

- mouth – [48, 68];
- right eyebrow – [17, 22];
- left eyebrow – [22, 27];
- right eye – [36, 42];
- left eye – [42, 48];
- nose – [27, 35];
- jaw – [0, 17].

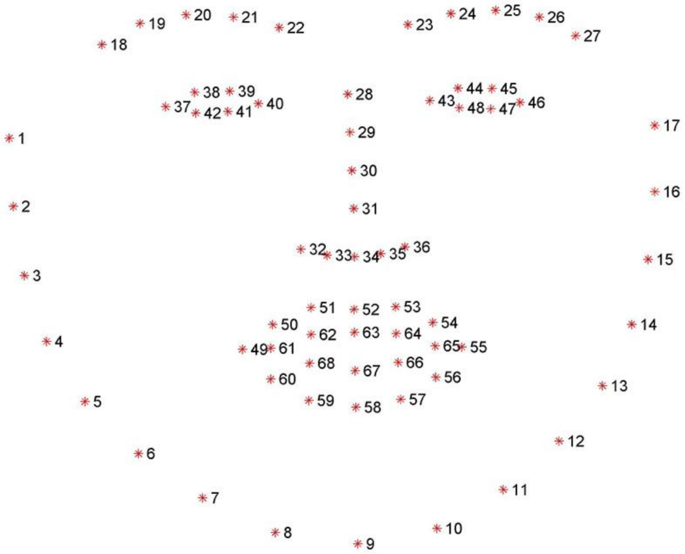

Fig. 2. 68 (x, y) coordinates that reflect specific facial structures

The main element of the face for monitoring is the eyes. Recognizing the eye positions, each eye is described by six coordinates in two-dimensional (2D) space (fig. 3).

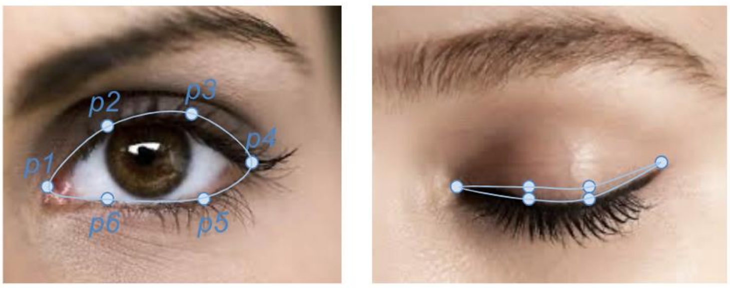

Fig. 3. The result of eye landmark recognition: open and closed eye

In order to detect a condition of the open or closed eye, we perform the calculation of the eye aspect ratio (EAR) between the height and width of the eye (1) [8]:

$$EAR = \frac{\| p_2 - p_6 \| + \| p_3 - p_5 \|}{2 \| p_1 - p_4 \|}, \quad (1)$$

where $p_1, p_2, \ldots, p_6$ are the 2*D* landmark coordinates, depicted in fig. 3.

Based on the eye aspect ratio, we can implement a classifier to predict the state of an open or closed eye. To do this, we need to define a boundary for the separation of two classes (open eye and closed eye). After the investigation, a limit was set that fluctuates within [0.25; 0.3]. In the morning driving, EAR for an open eye is greater than 0.25, in the evening – more than 0.3. This behavior is observed because in the evening driving the area of an open eye is smaller than in the morning due to the influence of less light and backlight cars [fig. 4, 5].

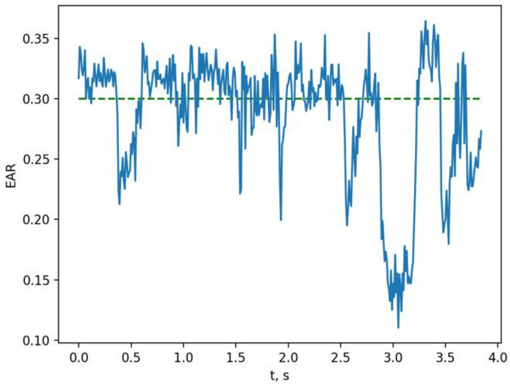

Fig. 4. EAR in the evening

Usually, the blinking frequency in humans can be considered unchanged if there are no external influencing factors. Accordingly, blinking often increases during long-term travel, which should be considered as a trigger for an early sleep.

The next monitoring factor is the monitoring of driver inattention while driving. Driver inattention is long glances in the side, sleep, use of smartphones or other devices while driving, and so on.

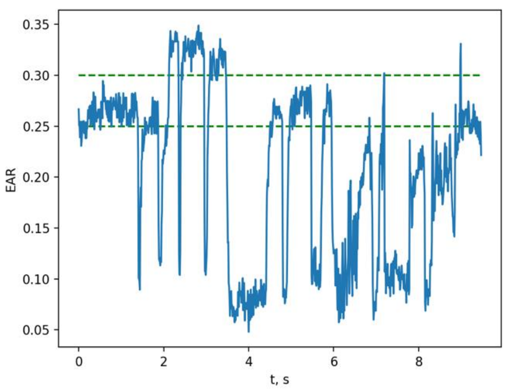

Fig. 5. EAR in the morning

The object of observation is the eye positions in two-dimensional spaces (x, y). Because there are limitations in computing power, a simple and fast method of machine learning classification is used – Naive Bayes classifiers.

Naive Bayes classifiers are built on Bayesian classification methods. These rely on Bayes's theorem, which is an equation describing the relationship of conditional probabilities of statistical quantities. In Bayesian classification, we're interested in finding the probability of a label given some observed features, which we can write as *P(L | features)*. Bayes's theorem tells us how to express this in terms of quantities we can compute more directly (2):

$$P(L \mid features) = \frac{P(features \mid L)P(L)}{P(features)} \tag{2}$$

If we are trying to decide between two labels (let's call them L_1 and L_2) then one way to make this decision is to compute the ratio of the posterior probabilities for each label (3):

$$\frac{P(L_1 \mid features)}{P(L_2 \mid features)} = \frac{P(features \mid L_1)P(L_1)}{P(features \mid L_2)P(L_2)} \tag{3}$$

Now we need a model by which we can compute $P(features \mid L_i)$ for each label. Such a model is called a generative model because it specifies the hypothetical random process that generates the data. Specifying this generative model for each label is the main piece of the training of such a Bayesian classifier. The general version of such a training step is a very difficult task, but we can make it simpler through the use of some simplifying assumptions about the form of this model.

This is where the "naive" in "naive Bayes" comes in: if we make very naive assumptions about the generative model for each label, we can find a rough approximation of the generative model for each class, and then proceed with the Bayesian classification [4, 5].

We used Gaussian naive Bayesian classifier. In this classifier, the assumption is that data from each label is drawn from a simple Gaussian distribution. One extremely fast way to create a simple model is to assume that the data is described by a Gaussian distribution with no covariance between dimensions. This model can be fit by simply finding the mean and standard deviation of the points within each label, which is all you need to define such a distribution [5, 6].

Figure 6 shows the results of the Gaussian naive Bayesian classifier. Where the circles reflect the probability levels of the point to the cluster center. According to the probabilistic prediction, we can monitor the events of the driver's inattention, if his eye positions are outside the confidence interval.

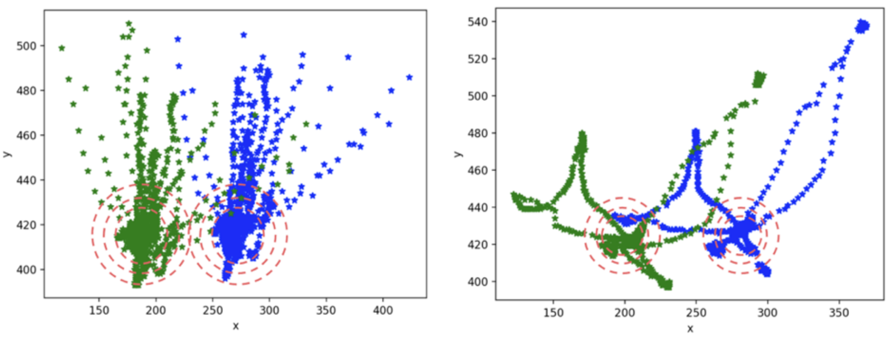

Fig. 6. The result of the Gaussian naive Bayesian classifier

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Testing of the monitoring system

According to the described researches, the Driver behavior system was implemented. Figures 7, 8 show the results of the system in the morning and evening. The implemented system is a concept of the future system, which shows the possibility of research development.

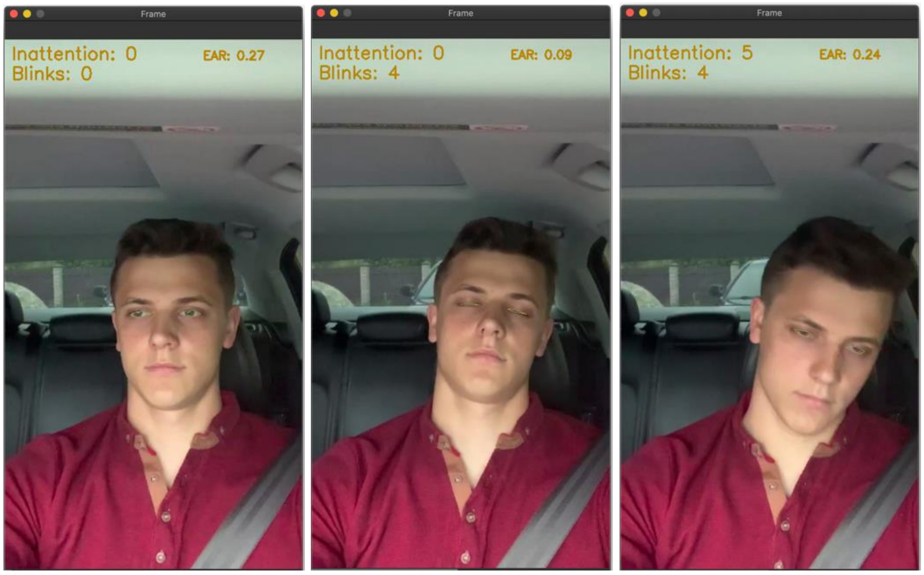

Fig. 7. Testing system in the morning time

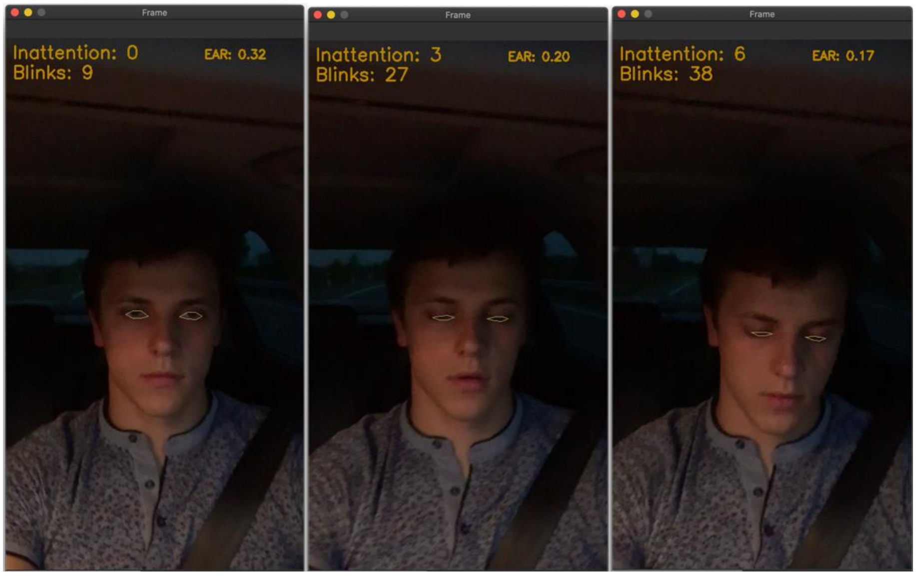

Fig. 8. Testing system in the evening time

Data Security

The system only works offline. That is, everything works locally on the device you use, similar to Face ID technology, where all data is processed on the device itself to ensure maximum data processing speed and security.

In addition, each frame from the video stream is processed to find a person's face and its elements (eyes, nose, ears, lips and chin), then the system uses only positioning in 2D space of face elements as (x; y). No data from the camera is stored. Warning statistics are stored only locally on the device and only with the driver's consent. The driver can prohibit the collection of statistics or delete the entire history if permission has been granted to record events.

Conclusion

In our study, we have shown an approach to identifying the special features of the object of observation and the classification of features to recognize the driver's behavior while driving. Methods for monitoring eye-opening / closing based on eye aspect ratio and inattention monitoring using the Naive Bayesian classifier were considered. The results of the system of monitoring a driver's behavior behind the wheel of the car are given. The implemented system is a concept of the future system, which shows the possibility of research development and a feature of such a system is its work in offline mode. In the next article, we will look at a detailed overview of how the system works on a low-power microcomputer in offline mode.

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СИСТЕМА СПОСТЕРЕЖЕННЯ ЗА ПОВЕДІНКОЮ ВОДІЯ

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В цій роботі розглядається система спостереження за поведінкою водія, який перебуває за кермом автомобіля. Основною метою є реалізація системи з використанням методів детекції та моніторингу об'єктів у відео потоці даних, яка буде працювати у реальному часі з використанням малої обчислювальної потужності та низького енергоспоживання для обробки даних.

У кожному авто є дзеркало заднього бачення. Ідеєю є заміна цього дзеркала на розумне дзеркало, яке буде виконувати моніторинг поведінки водія за допомогою відео-спостереження та повідомляти його у разі небезпеки у форматі звукових повідомлень. Крім цього, дзеркало буде мати можливість взаємодії з мультимедією автомобіля, що дасть можливість доступу до аудіо-виходу авто чи використання інших функціональних компонентів авто, щоб вчасно повідомити водія про небезпеку і забезпечувати функціонування системи тільки під час руху авто.

Система працює тільки в автономному режимі, тобто все працює локально на малопотужному мікрокомп'ютері і всі дані з камери обробляються на самому пристрої, щоб забезпечити максимальну швидкість обробки даних та їх безпеку. Зокрема, дані з камери не зберігаються, а статистика попереджень зберігається тільки локально на пристрої і тільки за згодою водія.

Модель системи складається з двох частин: виділення орієнтиру очей та застосування Naive Bayes класифікатора для визначення поведінки водія на ознаки стомлення, засинання та відволікання під час водіння автомобіля. Реалізована система є концепцією майбутньої системи, яка показує можливість розвитку досліджень і особливістю такої системи є її функціонування в автономному режимі.

Ключові слова: розпізнавання об'єктів, орієнтири обличчя співвідношення сторін очей, Naive Bayes класифікатор, безпека даних.

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