Stabilization of environmental conditions to improve the performance of a mobile application for the state of the driver monitoring

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***Abstract*—The use of modern digital technologies in the field of security enhancement is a promising area of research. The results of a study in the field of increasing the level of human security in the case of monotonous, routine work using neural networks were reported at the AIS2021 conference. It has been developed a model and an algorithm for detecting a dangerous state of the driver (wakeful or sleeping). This work has been continued. The conditions of the environment in which the developed software is intended to be used depend on the smartphone used and how the smartphone is mounted in the vehicle. It should be noted that in a real environment, smartphones work with not always complete and accurate data. These factors directly affect the performance of the mobile app by changing the speed, accuracy, and functionality of the mobile app. This paper presents algorithms for manual and automatic calibration of the system based on data from the camera, sensors and settings of the driver's smartphone. It is proposed to use a mandatory calibration method that adapts to the current context of the driver and vehicle in order to reduce errors in various calculations of physical quantities numerical values and ensure the uniformity of measurements during the operation of the system. The calibration takes into account the input information about the driver, vehicle and smartphone. The processing of the critical area and the state of the driver in the image were implemented in the C ++ programming language using the computer vision software libraries OpenCV and Dlib, and the JNI interfaces were realized in the Java language.**

Keywords—neural networks, emotions recognition, software development

I. Introduction

Currently, there are enough works aimed at improving human safety with the help of driver monitoring systems. Some scientists use methods and algorithms for tracking the closed eyes of the driver in their developments. For example, in the article [1] such models are used. Attention is paid to the health of the driver, for example, pulse, pressure, temperature are measured [2]. The paper [3] uses equipment to control the biometric indicators of the driver. In a study [4], published by us in the journal JATIT, the method of video analytics was used. The article [4] provides a detailed analysis of the literature on the research topic over the past 5 years. The results of a study in the field of increasing the level of human security in the case of monotonous, routine work using neural networks were reported at the AIS2021 conference [5]. At the moment, we have paid attention to the problem of environmental conditions in the cabin of the vehicle. How the smartphone is fixed in the car, as well as the phone model, directly affect the performance of the mobile application, its speed, accuracy and functionality. To solve this problem, it is supposed to use a mandatory calibration method that adapts to the current context of the driver and vehicle. The calibration takes into account the input information about the driver, vehicle and smartphone.

II. Manual calibration of the system

From a technical point of view, the method of calibrating a certain parameter is the determination of the characteristics of the deviation of a particular physical quantity associated with the measurement conditions, namely, the comparison of the numerical value of a physical quantity measured using the driver's smartphone with a separate value or falling into the measurement range, previously measured and established on the basis of analysed scientific studies and test data from drivers of a driver condition monitoring system. By analysing and taking into account the profile and contextual information about the driver and the characteristics of the hardware and software of the smartphone, two calibration modes were identified by the nature of the implementation, which are the initial manual calibration carried out directly by the driver of the vehicle and automatic calibration - already in the process of using the mobile application.

Manual calibration of the system is mandatory at the first start after installation and can be recommended to the driver if there is a need to re-configure and adapt the mobile application to the current conditions of use.

This type of calibration is intended to ensure the initial correct operation of the monitoring system. When using manual calibration, the parameters (Figure 1) to be calibrated are the position and size of the driver's face and head (the face is directed to the smartphone's front camera, there are no foreign objects obstructing the view in the visibility zone, and the face itself does not go beyond the boundaries of the smartphone's camera viewfinder), the volume level of audible warning signals, etc.

Fig. 1. Normal positions

The parameters characterizing the position of the driver's head are the angle of inclination and the angle of rotation of the head (see Figure 2).

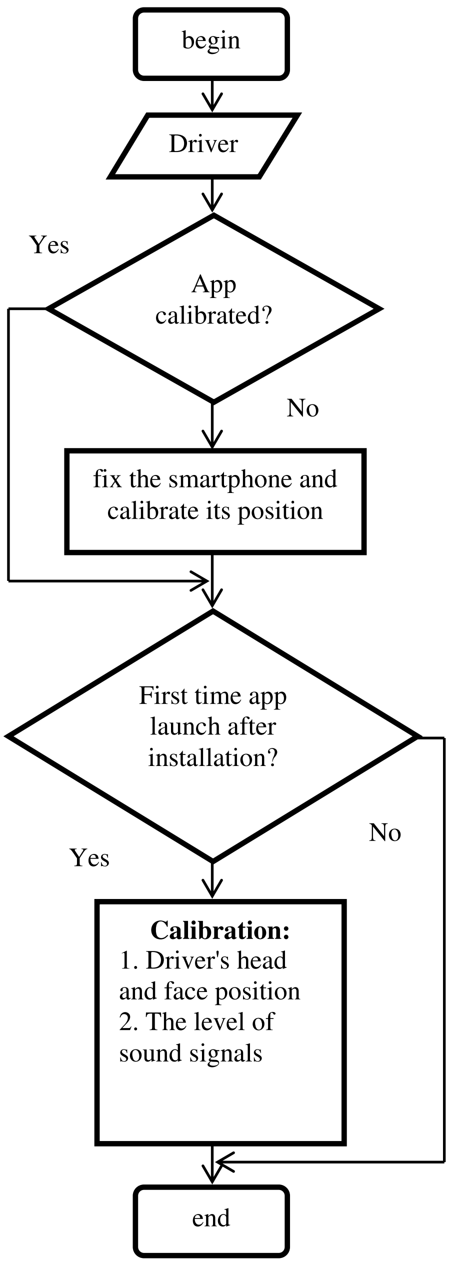

Fig. 2. Manual calibration algorithm

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

III. AUTOMATIC CALIBRATION OF THE SYSTEM

In addition to the manual mode, the automatic mode is another option for using calibration, which consists in program setting and adaptation of the parameters of the mobile software complex of the monitoring system without the participation of the driver during the operation of the application. The automatic calibration mode is mainly used in the case when during the operation of the monitoring system a large number of consecutive false alarms about dangerous conditions occur in the absence of a reaction from the driver, confirming or rejecting this or that event. In this case, as a result of applying this calibration mode, the dangerous states detected by the monitoring system are transferred to the "non-dangerous" category and are taken into account by the system when further adapting the mobile software package to the driver's driving style.

The automatic calibration mode is described in more detail as follows. Images of the face of one driver, obtained as a result of the operation of the front camera of a smartphone at various positions of his head, including the angle of rotation to the left or right, or its angle of inclination forward or backward, are one of the main sources of information used by the monitoring system when determining a dangerous condition. Thus, the characteristics of the head position have a direct impact on the operation of the facial characteristics recognition module from the frontal image of the driver's face.

The automatic calibration mode algorithm (see Figure 3) consists in iterative and regularly repeated adjustment of the driver's facial characteristics by assessing and taking into account deviations in the angles of inclination and rotation of the head in the plane of the front camera of the smartphone.

A predetermined number of measurements (observations) of the driver's head position angles, collected over a certain time series in the process of performing automatic calibration, make it possible to describe each input image from the video sequence of the smartphone's front camera by a set of certain real numbers denoting the degree of head rotation and inclination in the range from 0 ° up to 360°. A threshold operation is applied to the resulting interval set of numbers calculated for each image, which makes it possible to filter out the values that make the set noisy with inconsistent values. For example, as a threshold operation, you can choose the lower (or upper) threshold so that the number of frames from the video sequence in which the tilt (or rotation) angle exceeds the threshold is less (or more) than the predicted proportion of all observed images from the front camera of the smartphone.

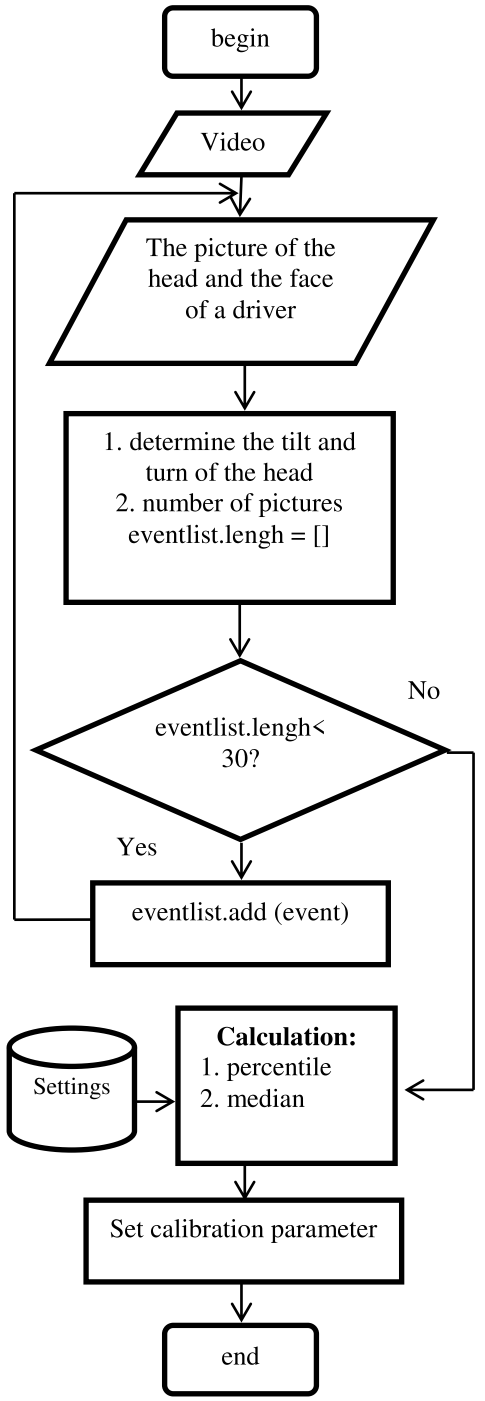

Fig. 3. Automatic calibration algorithm

The described method is based on the use of a percentile represented by such a number that the given random value does not exceed it only with a fixed probability given in percent. The final step in the automatic calibration mode is the calculation of the median of the filtered range of values. It will determine the calibrated observed parameter (head tilt or turn) and save it to the driver settings stored on the smartphone.

It is known, that the calibration process is based on information about the objects that are captured by the camera: their proportions, orientation, and spatial position (see Figure 4).

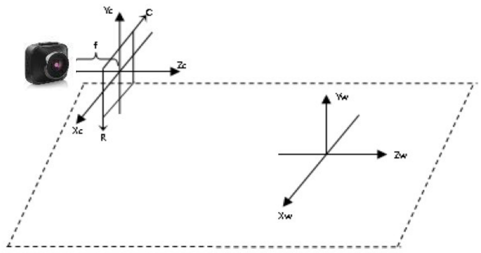

Fig. 4. The model of the visual system of the surveillance camera [4]

The model of the visual system of the surveillance camera includes:

- Rectangular image coordinate system with integer R and C axes, where R and C coordinates are the numbers of rows and columns of pixels in the image.

- Rectangular camera coordinate system with real axes Xc, Yc, Zc.

- Rectangular world coordinate system with real axes Xw, Yw, Zw.

The optical center in the camera system has coordinates (0, -f, 0). The image plane RC, modeling the camera matrix, lies in the XcYc plane, and the Zc axis is the optical axis of the camera [4]. This model is described in details in our research paper [4].

IV. Software

It was found as a result of the experiments that the resolution of the processed image in width and length, not exceeding 300 pixels on each side, is sufficient for most modern smartphone models.

The processing of the critical area, the state of the driver's behavior in the image, was implemented in the C ++ programming language using the computer vision software libraries OpenCV and Dlib, and the JNI interfaces were implemented in the Java language. The OpenCV open cross-platform computer vision library developed by Intel, as well as the Dlib machine learning library, greatly simplifies computer vision programming by providing a convenient interface for face detection, tracking and recognition. An important component in OpenCV is the mathematical apparatus and functionality for image processing.

In the general case, the process of image processing and face search consists of the following successive steps: face detection and localization in the image, face image alignment (geometric and brightness), feature calculation and direct recognition - comparison of the calculated features with the standards stored in the database.

An approach is used for each frame coming from the front camera of a smartphone to analyze facial characteristics based on combining image processing algorithms from the Dlib and OpenCV libraries, implemented in C ++ and focused on selecting faces, key points on it and working with these points. The following algorithms are used to search and highlight facial characteristics in images, which are included in the package from Dlib:

- Calculation of descriptors by the method of histogram of directed gradients (HOG, Histogram of Oriented Gradients) and search for faces in the image;

- Use of the support vector machine to classify descriptors;

- Application of a set of decision trees (Random Forest) to select 68 key points on a human face (see Figure 5).

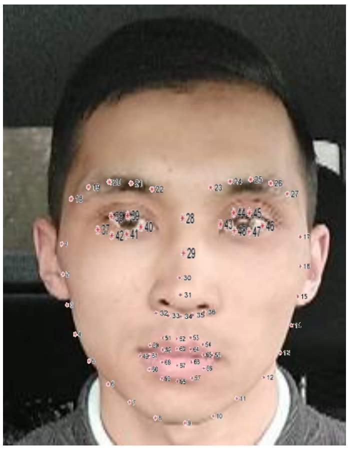

Fig. 5. Program settings window

The mobile application sets a time period equal to 10 seconds, to ensure the completeness and accuracy of the calculated parameters, during which the results of the analysis of the driver's facial characteristics are accumulated from the front camera of the smartphone.

This task is performed using Android's built-in CountDownTimer class, which allows you to implement a programmatic countdown timer. During this calibration, the driver's head must be directed straight ahead in the direction of the vehicle. The CircularFifoQueue class is a standard implementation of this type of queue from the Apache Commons Collections library. The return parameter of the findAverage function is an object of the Pair system class, containing as the first argument the SMA (Simple Moving Average) for the head left/right angle, and the second argument SMA for the forward/backward tilt of the driver's head. Calculation of the calibrated parameters of the driver's head on the interval private fun findAverage (list: CircularFifoQueue<PureDistraction>):

```
Pair<Float, Float> {
val iter = list.iterator()
var sumYawAngle = 0f
var sumPitchAngle = 0f
while (iter.hasNext()) {
val item = iter.next()
sumYawAngle += item.yawHead.angleHead.detectedAngleValue
sumPitchAngle += item.pitchHead.angleHead.detectedAngleValue }
val size = list.size.toFloat()
val yaw = sumYawAngle / size
val pitch = sumPitchAngle / size
return Pair(yaw, pitch) }
```

The mobile application installed on the driver's smartphone is designed for devices based on the Android operating system with the minimum supported version of Android 4.2. It is a result of our work.

Our system has a number of advantages despite of many very good existing developments in the field of driver monitoring:

1) Portability, because the system is installed on the driver's smartphone and can be used in different cars by the same person.

2) The cost for local Kazakh drivers is lower than the cost of proposed existing systems by about 30%.

3) The system is adapted to local road conditions (roughness of the road surface in some places, off-road, sharply continental climate, causing extreme fluctuations in temperature, etc.).

4) Our software can be customized for a specific driver to improve the accuracy of situation recognition.

We are going to continue the research and realize special platform for smartphone holder.

V. Conclusion

Algorithms have been developed for automatic and manual calibration of the driver's condition monitoring system based on data from the camera, sensors and settings of the driver's smartphone in order to minimize the influence of external conditions on the implementation of the mobile application and to maximize the adaptation of the system for the driver. All the considered methods and algorithms are implemented in a software package in the C # programming language and Java.

Acknowledgment

Part of the research was carried out with the support of the East-Kazakhstan technical university.

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