# Driver Drowsiness Detection based on Blink Ratio and Contour Area methods

1st Shyngyskhan Abilkassov
*Robotics and Mechatronics*
*Nazarbayev University*
Astana, Kazakhstan
shyngyskhan.abilkassov@nu.edu.kz

2nd Merey Kaiygaliyev
*Robotics and Mechatronics*
*Nazarbayev University*
Astana, Kazakhstan
merey.kaiyrgaliyev@nu.edu.kz

3rd Bauyrzhan Zhakanov
*Robotics and Mechatronics*
*Nazarbayev University*
Astana, Kazakhstan
bauyrzhan.zhakanov@nu.edu.kz

***Abstract*—Driver's drowsiness is one of the major problems around the World. In 2018, there were more than 15000 car accidents in Kazakhstan. In order to minimize the number of deaths and terrific circumstances on the road, the paper based on survey aims to compare two methods of the identification of driver drowsiness via OpenCV C++ platform. In both methods, the algorithm uses video feed focused on the driver's face and tracks eye and mouth movements. First method is implemented via Blinking Ratio method using 68-landmarks of the face by calculating the blinking and yawning ratio, while the second one uses the Contour Area method for drowsiness identification with the help of Viola-Jones algorithm for face, eyes detection. 68 coordinates has been also considered to detect mouth features. The drowsiness is identified after some eye closure and yawning rates, and an alarm is activated if the driver is drowsy.**

***Index Terms*—OpenCV, Region of Interest, Viola-Jones, 68-landmarks, Haar-cascade**

## I. Introduction

Despite the fact that global trends are proposing fully autonomous vehicles, human drivers will still be an essential part on the road traffic. However humans have their own flaws, one of which is a drowsiness during driving a car for prolonged time period. It is of special importance for Kazakhstan - the country with a fatality rate of 24.2 deaths per 100,000 habitants [1]. In 2018 alone, there were 15,771 car accidents on Kazakhstani roads, which caused a total of 2,096 deaths and 20,455 injuries [2]. Moreover, the nearest Kazakhstan cities are located 5-6 hours drive from each other which makes driving for longer periods of time more dangerous. The road between cities can significantly cause fatigue for drivers, as a result of which they can lose their vigilance. Micro sleeps that occur with humans may continue 30 seconds [3]. This amount of time is enough to lose focus and create vulnerability on the road by dramatically decreasing the reaction rate of the driver.

Since the person is under the influence of inattentive circumstances, the outside observer or tool can monitor their behaviour based on different factors such as eyes closure, yawning, heart rate, and body temperature. Understanding the importance of this issue led many scientists and engineers around the world to provide the different methods and techniques in order to solve a problem. The methods can be differently come up with a solution such as the number of inputs or algorithms. Nowadays, many research fields are oriented in machine and deep learning techniques like classification of driver's head and eyes position because of their non-invasiveness and ease of installation. Based on the survey state-of-the-art drowsiness detection techniques, we consider the Blinking Ratio and the Contour Area methods, since both methods are using two different techniques for an eye state estimation [9]. The first method is using the technique of Ahmad et al. paper that is published in International Journal of Computer Science and Information Technologies [7]; meanwhile the second method proposed by Nguyen et al. is published in 6t International Conference on Automation, Robotics and Applications (ICARA) in 2015 [8]. In this paper, we implement two existing methodologies that are aimed to detect the driver drowsiness based on computer vision techniques. The purpose of this project is to implement both algorithm, develop stable pipeline and interface and identify their effectiveness.

## II. Methodology

Both methods have six stages as described in the following Fig 1. Testing of these methods is done by using the web camera of a laptop.

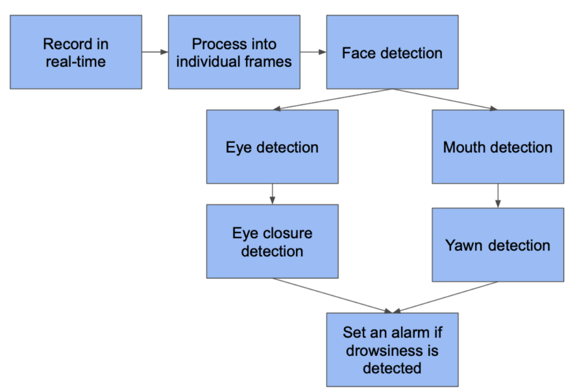



Fig. 1: The general block diagram proposed algorithm of drowsiness detection

### A. *Pre-processing*

The web camera is located in front of the driver, and focused on his face. In the proposed methods, the processing rate of video is 30 frames per second. For the testing purposes prerecorded videos were used. Recorded video are converted into the sequence of frames, whereas each RGB frame is converted into the gray scale format. In the case when face is not found nothing is considered and automatically moved to the next frame, similar to the cascade classification methodology. The flow chart of this sequence is shown in the Fig 2.

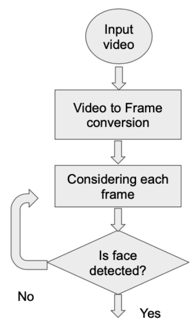



Fig. 2: Partial flow chart from input video to face detection

### B. Face Detection

One of the widely used and popular techniques for face detection is cascading recognition system based on Viola Jones technique for detecting faces that is called Haar-based classifier. This classifier is containing features as heights, weights, face features, and the threshold of face colors [4] [5].

### C. Facial mapping using 68 landmarks

The technique is proposed to detect the key facial structures in the face region based on 68 point landmarks [6]. All those points are essential for the localization and labeling of the key features such as mouth, right eyebrow, left eye brow, right eye, left eyes, nose, and jaw lines. The trained set of labeled landmarks specify (x, y) coordinates of the regions and estimate positions based on the pixel intensity. The indexes of 68 points are visually represented in the Fig 3.

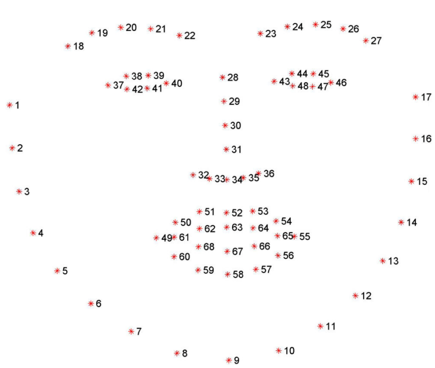


Fig. 3: Visual representation of 68 facial landmark

### D. Two proposed methods for eyes closure

Face detection significantly simplifies the computation for finding other features. There are two proposed techniques for eye closure detection detection: The Blinking Ratio method and The Contour Area method. One significant difference between the two methods is the way of getting the state of the eye. The first method is using 68 landmark coordinates to get left and right eyes. Each individual eyes points as Region of Interest are used to crop the eye region. Afterwards, polygon mask is applied for each cropped region in order to leave the eye area visible. Calculating the ratio between width and height is showing the eye state. The second method is using Haar-cascade classifier for getting the eye region. Morphological operations as bilateral filtering, dilation, erosion, and the conversion to gray scale and binary image are applied to get a black and white image. Afterwards, an eye state is estimated by the ratio between black and white pixels, which is essentially showing the size of the iris relative to the rest of the eye region. Fig 4. shows the main differences of both methods.

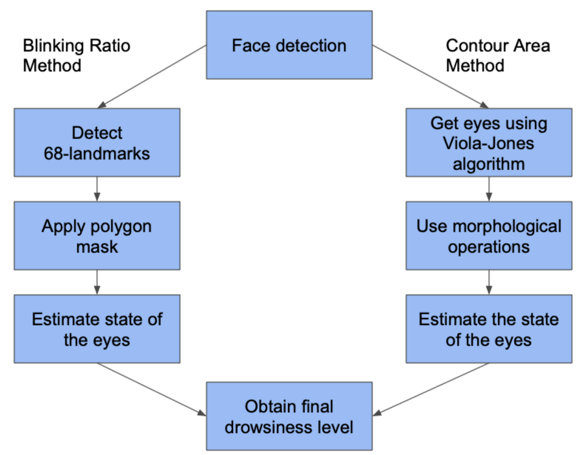



Fig. 4: The proposed methods for eye closure detection

*1) The Blinking Ratio method:* The Blinking Ratio method is focused on the identification of parameters that represents the eye state in order to figure out whether the eyes are in open or closed state [7]. It can be calculated using 68 facial landmark point predictor. Right eye is considered as points from 37 to 42, meanwhile left eye points are from 43 to 48. Points in the region of interest are used to calculate the ratio between width and height of the eye. Width can be found by subtracting the most left point of eye to the most right point, while height is calculated using middle point between two upper and two lower points. The blinking ratio between width and height is calculated by diving width to the height. If the ratio is less than the considered threshold, the person is blinking.

Afterwards, as proposed in the [7], the average drowsiness is calculated as follows:

$$\%_{drowsiness} = \frac{\text{no. of closed eyes found}}{\text{no. of frames}} * 100 \quad (1)$$

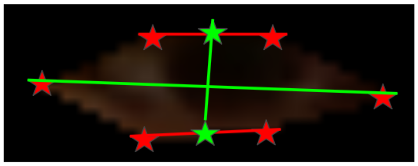


Fig. 5: The Blinking Ratio method

*2) The Contour Area Method:* This method is based on detection of driver's eyes as region of interest using Viola Jones algorithm and afterwards extracting eyes features using the morphological operations [8]. One of the notable differences of this work is that Nguyen et. al. used contour mask for eye closure detection whereas others mostly use distance between the eye region landmarks instead. The extraction of an eye has been produced with image processing operations. First of all, bilateral filtering is applied for cropped image to reduce the noise of an image. This filter substitutes the intensity of each pixel with a weighted average of intensity values from surrounded pixels. Secondly, each filtered frame is converted to gray scale in order to simplify the conversion into binary image. The resultant image is converted into binary image using the dynamic threshold. Finally, the morphological operations with 5x5 matrix are performed: the erosion is applied in order to get rid of the distant single black pixels outside of iris, then followed by dilation for filling the small white regions inside of the iris due to light reflections.

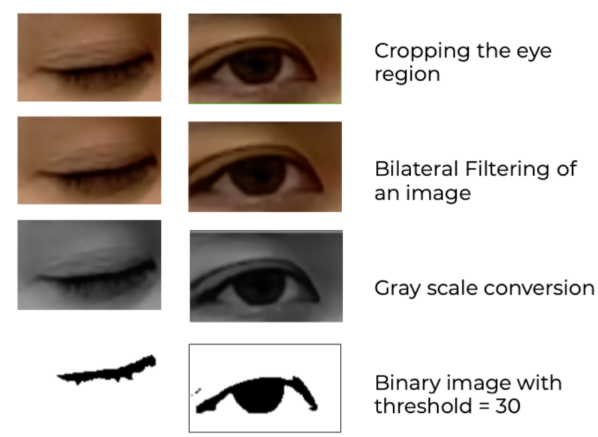



Fig. 6: The Contour Area method

Area Ratio is then calculated by dividing the number of black pixels to the total number of pixels. If an Area Ratio is less than the specified threshold, then the prediction is that the person is in blinking state. Specified threshold is considered as 0.3, since this value corresponds to the lower boundary of area ratio when the eye is fully open.

Afterwards, the average drowsiness is calculated as in the previous method.

### *E. Yawning detection*

Yawning is one of the features of driver's drowsiness. The characterization of yawning is simply wide open mouth. Using the facial landmarks, points in the region of interest is used for mouth detection. The process of detecting the yawning from mouth is calculated by finding the lip distance between upper and lower points and normalized by its width. Small mouth opening is ignored since these features are considered as talking, eating. If lip distance is higher than specified threshold, the subject is determined to be in the yawning state. Afterwards, each detected yaw is used to calculate average yawning similar to blinking:

$$\%_{yawning} = \frac{\text{no. of yawns found}}{\text{no. of frames}} * 100 \quad (2)$$

### *F. Drowsiness detection*

Driver drowsiness is calculated if the number of yawns is more than the threshold or the number of blinking frames are occurred more than specified boundary. In that cases, an alarm is set when the subject has blinked and yawned more than the boundary value in the specific amount of time which is taken as 20 frames. The flow chart of the drowsiness detection algorithm is presented in the Fig 7.

## III. Results and Findings

### *A. Blinking Ratio Method and Yawning*

During experimental testings, following observations were made:

- Estimation of the drowsiness based on each 20 frames on video with frame rate of 30 fps is sufficient
- If average blinking ratio calculated in the previous section is exceeding value of 3.8 it can be assumed as closed eye
- If the driver's eyes are closed for prolonged periods of time, on average it exceeds the value of 16 instances in every 20 frame
- Yawning ratio less 1.7 is considered to be driver's yawning state

Finally, these thresholds and values were incorporated into the final implementation of the original proposed algorithm. Moreover, special interface in C++ was developed to visualize the process of driver drowsiness estimation.

Fig. 8(a) illustrates the normal and focused state of the driver, then Fig. 8(b) shows the drowsy state of the driver, where driver's drowsiness percentage is exceeding preliminary defined threshold value. Finally, Fig. 8(c), illustrates the case where driver is yawning for some period of time, but it is not exceeding the threshold which defines drowsiness, therefore no alarm is activated.

### *B. Contour Area Method*

The Contour Area method has shown to be effective from the beginning. However, there were possibilities for improvement. One of the most critical issues appeared during implementation of this method is that initially threshold value was defined by hand and changed statically. However, the dynamic

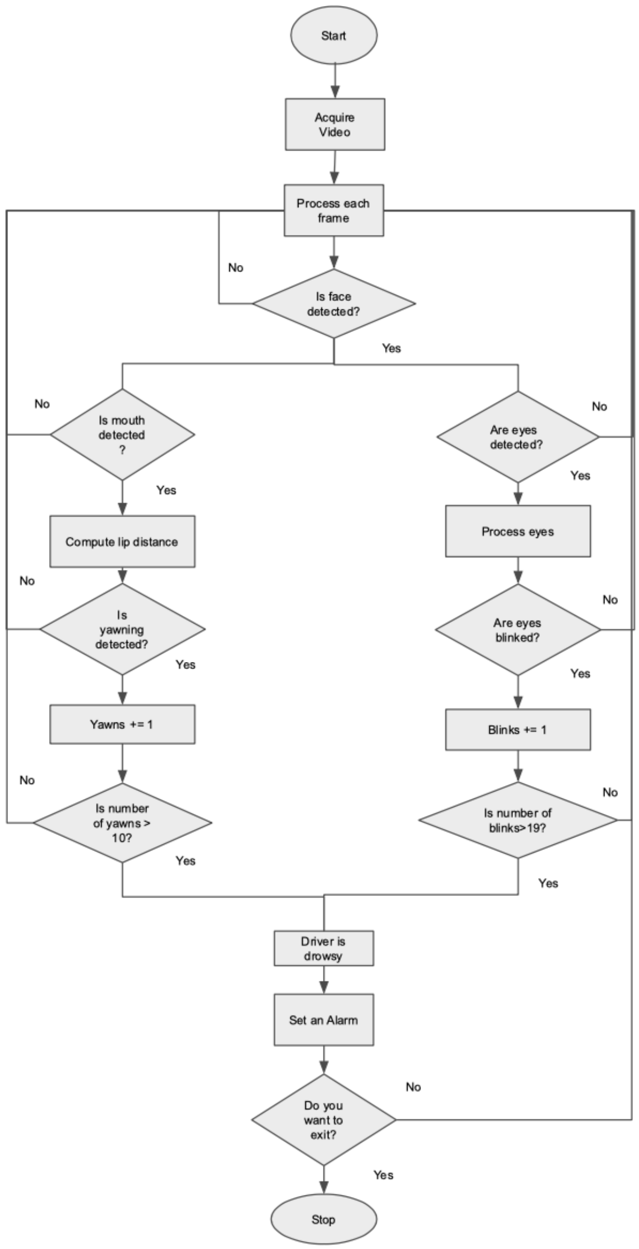
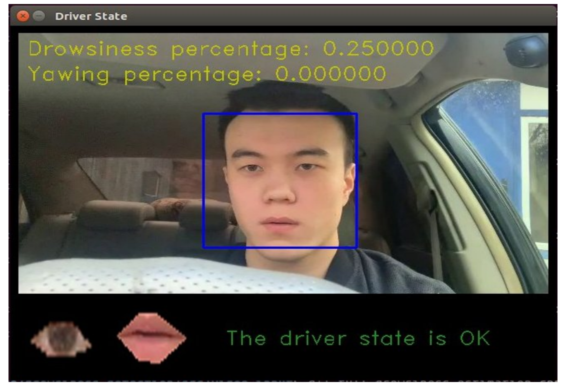
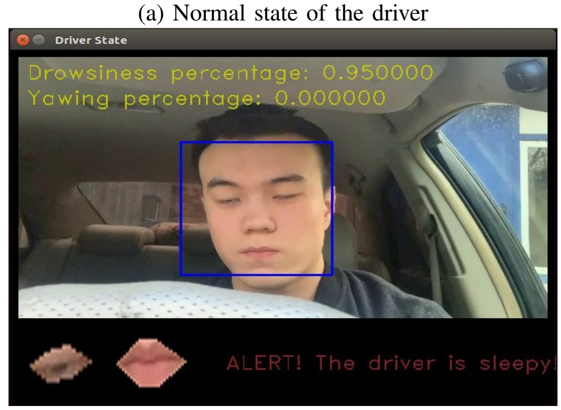


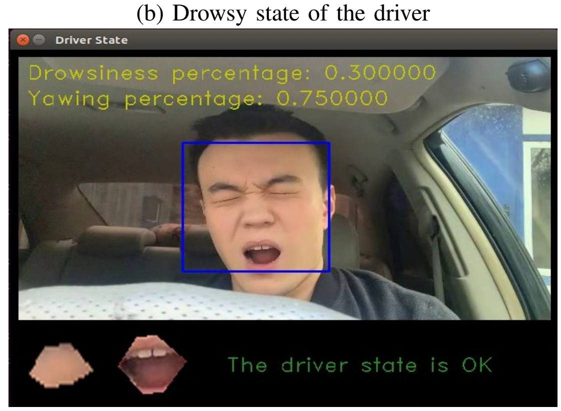

Fig. 7: The flow chart describing the drowsiness detection algorithm




(a) Normal state of the driver




(b) Drowsy state of the driver




(c) Yawning state of the driver

Fig. 8: Visualization of the interface for driver state estimation

threshold search function was implemented. One of the key features of this method, is that it allows to obtain desirable iris contour in different lightning conditions.

Firstly, it was found that on average person's iris (region filled with black pixels) to the remaining white background ratio is on average around 0.45. Afterwards, the RGB image with eye region is fed to the function that loops through different threshold values from 5 to 100 and calculates the iris size ratio. Finally, the threshold value which gives the closest result to the 0.45 value is saved. This done on 20 consecutive frames and the average is used for following threshold and drowsiness estimation. Therefore, on video with 30 fps, the calibration procedure is taking less than one second.

One additional step has been performed in order to reduce the number of false positive predictions: the morphological closing. This step includes the calculation of the ratio of horizontal distance to vertical, so that if the resultant ratio exceeds the predefined value of 2.3, the contours are not considered further. In this manner, only contours that have circular or square shapes (such as iris) are preserved, whereas elongated shapes (e.g. eyelids when eye is closed) are defined to have no contour. The differences can be noted from the comparison below in Fig. 9.

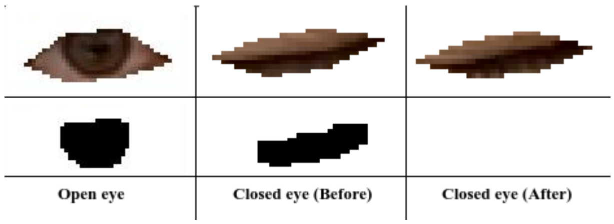



Fig. 9: Binarizations of eye region images with and without corrections for eyelids

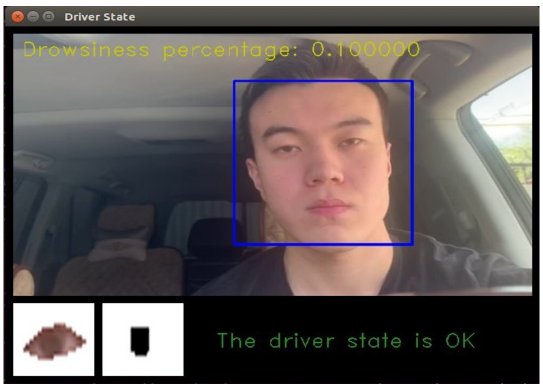



Fig. 10: Visualization of driver state estimation based on area contour method

### *C. Open source implementations*

Although, there are plenty of scientific papers and research findings being published on a constant basis related to the drowsiness estimation, there is a gap of open source implementations of these algorithms. Moreover, currently there is no unique benchmark that could be used to compare different algorithms for this task and no way of finding what may suit one's aims best. In order to mitigate this problem, the authors have decided to make their work on implementing blink ratio and contour area methods open source. This should allow for researchers and engineers to understand working principles of these algorithms and find what better suits them. Moreover, anyone is welcome to contribute to this work. Authors are hopeful that this work can help both researchers to implement novel techniques and engineers to launch drowsiness estimation into the roads and therefore make everyone's life safer.

## IV. Conclusion and Future Work

The proposed algorithm of both methods detects the driver's drowsiness state based on eye closure and yawning. The system is tested on real car simulation and also in real-time. Both methods have shown accurate estimation of the driver's state and prediction of the drowsy condition. Thanks to the dynamic calibration of the thresholds for binarization and multiple techniques for removal false positive in area method and robust detection of landmarks features in blink ratio methods have shown good performance under different lighting conditions and changing environment. However, due to the limitations of the cameras the drowsiness detection works only in restricted illumination conditions which requires existence of a daylight or artificial lighting in the car interior. In order to track driver's condition during the night, it is necessary to work with an IR camera in the future. Moreover, system combining two approaches may give a better results, but this may impact computation time and become a burden on computation units.

## References

[1] World Health Organization (2018). Global Status Report on Road Safety 2018 (pp. 392–397).
[2] Committee on Legal Statistics and Special Accounts of the General Prosecutor's Office of the Republic of Kazakhstan (2018). Statistics of Road Traffic Accidents in 2013-2018. http://stat.gov.kz/official/industry/18/statistic/7
[3] International Classification of Sleep Disorders and Coding Manual, "Archived copy" (PDF). Archived from the original (PDF) on 2011-07-26. Retrieved 2011-7-26., page 343.
[4] Viola, Jones, Rapid object detection using a boosted cascade of simple features, Computer cool Vision and Pattern Recognition, 2001.
[5] Li Cuimei, Qi Zhiliang, Jia Nan, Wu Jianhua, Human face detection algorithm via Haar cascade classifier combined with three additional classifiers, IEEE 2017.
[6] Davis E. King, Dlib-ml: A Machine Learning Toolkit, Journal of Machine Learning Research 10 (2009).
[7] R. Ahmad and J. N. Borole, "Drowsy driver identification using eye blink detection," Int. J. Comput. Sci. Inf. Technol., vol. 6, no. 1, pp. 270–274, Jan. 2015.
[8] T. P. Nguyen, M. T. Chew, and S. Demidenko, "Eye tracking system to detect driver drowsiness," in Proc. 6th Int. Conf. Automat., Robot. Appl. (ICARA), Feb. 2015, pp. 472–477.
[9] Ramzan, M., Khan, H. U., Awan, S. M., Ismail, A., Ilyas, M., Mahmood, A. (2019). A survey on state-of-the-art drowsiness detection techniques. IEEE Access, 7, 61904-61919.