VISVESVARAYA TECHNOLOGICAL UNIVERSITY

JNANA SANGAMA, BELAGAVI-560 004

TECHNICAL SEMINAR REPORT

On

ADVANCED DRIVER ASSISTANCE SYSTEM FOR THE DROWSINESS DETECTION USING FACIAL LANDMARKS

Submitted in partial fulfilment of the requirements for the degree of

BACHELOR OF ENGINEERING
IN
ELECTRONICS AND INSTRUMENTATION ENGINEERING

Submitted by

SHANTANU N GHODGAONKAR

1BI17EI033

Under the guidance of

Dr. M. B. MEENAVATHI
Professor and Head
Dept. of Electronics and Instrumentation Engineering

Carried out at

BANGALORE INSTITUTE OF TECHNOLOGY

DEPARTMENT OF ELECTRONICS AND INSTRUMENTATION ENGINEERING
K.R. ROAD, V. V. PURAM, BENGALURU - 560 004.
2020-2021

BANGALORE INSTITUTE OF TECHNOLOGY

(Affiliated to Visvesvaraya Technological University)

K.R. ROAD, V. V. PURAM, BENGALURU-560 004

DEPARTMENT OF ELECTRONICS AND INSTRUMENTATION ENGINEERING

CERTIFICATE

This is to certify that the Technical Seminar entitled **ADVANCED DRIVER ASSISTANCE SYSTEM FOR THE DROWSINESS DETECTION USING FACIAL LANDMARKS**, bonafide work carried out by **Mr. SHANTANU N GHODGAONKAR** bearing USN **1BI17EI033,** a student of **Bangalore Institute of Technology** in partial fulfilment for the award of Bachelor **of Engineering in Electronics & Instrumentation Engineering** under **Visvesvaraya Technological University, Belagavi** during the year 2020-21. The report has been approved as it satisfies the academic requirements in respect of Technical Seminar as prescribed for the said Degree.

100

Signature of the Guide:

Dr. H. N. SURESH

Professor & PG Coordinator,

Dept. of EIE, BIT, Bangalore.

Signature of the HOD:

Dr. M. B. MEENAVATHI

Professor & HOD,

Dept. of EIE, BIT, Bangalore.

Date:

Place:

ACKNOWLEDGEMENT

The satisfaction and euphoria that accompany the successful completion of any task would be incomplete without the mention of the people who made it possible, whose constant guidance and encouragement crowned the efforts with success.

I express my deepest sense of gratitude to my guide **Dr. H. N. SURESH**, Professor and PG Coordinator, Department of Electronics and Instrumentation Engineering, B.I.T, for his constant support and guidance throughout the course.

I express my thanks to **Dr. M. B. MEENAVATHI**, Professor and Head, Department of Electronics and Instrumentation Engineering, B.I.T, for giving me all possible support and assistance for the completion of the course.

This acknowledgment will be incomplete without thanking my parents for their co-operation and even thanking teaching and non- teaching staff of Department of Electronics and Instrumentation Engineering, B.I.T for their co-operation and contribution either directly or indirectly.

I wish to express my profound gratitude to everyone who provided their valuable time and assistance in helping me to bring out the best.

SHANTANU N GHODGAONKAR

1BI17EI033

ABSTRACT

The increasing number of on-road vehicles provide immense number of opportunities as well as also leads to complications for safer and more secure movement of goods and passengers. The dynamic evolution of the automobile industry is attributed primarily to the changing consumer preferences, growing focus toward driver safety, environmental concerns, and stringent government regulations which are focusing toward crash avoidance rather than crash survival. In the past years, automobiles have undergone rapid technological advancements in terms of vehicle performance, passenger safety, communication capabilities, and driving comfort. These improvements have led to a surge in the number of on-road vehicles, thus raising the need for the safer movement of automobiles.

Advanced Driver Assistance Systems, or ADAS, are systems to help the driver in the driving process. When designed with a safe Human-Machine Interface, they should increase car safety and more generally road safety.

Conventional ADAS technology can detect some objects, do basic classification, alert the driver of hazardous road conditions, and in some cases, slow or stop the vehicle. This level of ADAS is great for applications like blind spot monitoring, lane change assistance, and forward collision warnings.

Although ADAS technology has the potential to transform the automotive sector, companies may need to conduct extensive testing to evaluate the safety of the ADAS component and the entire system under different environmental and operational conditions.

CONTENTS

CHAPTER 1	**INTRODUCTION**		
	1.1	History of ADAS	1
	1.2	ADAS for Drowsiness Detection	2
CHAPTER 2	**SYSTEM ARRANGEMENT**		
	2.1	Choice of Methodology	3
	2.2	Working Principle	4
		2.2.1 The Viola-Jones Algorithm	4
		2.2.2 Block Diagram	7
CHAPTER 3	**METHODOLOGY**		
	3.1	Stage 1: Image Capture	8
	3.2	Stage 2: Image Pre-processing	8
	3.3	Stage 3: Viola – Jones Algorithm	9
	3.4	Stage 4: Detection of Facial Landmarks	10
	3.5	Stage 5: EAR Calculation	11
	3.6	Stage 6: EAR Evaluation	12
	3.7	Results	12
CHAPTER 4	**ADVANTAGES, DISADVANTAGES, APPLICATIONS AND FUTURE ENHANCEMENTS**		
	4.1	Advantages	13
	4.2	Disadvantages	13
	4.3	Applications and Future Enhancements	13
		4.3.1 Applications	13
		4.3.2 Future Enhancements	13
CONCLUSION			14
REFERENCES			15

LIST OF FIGURES

Figure 1	SAE Automated Driving Levels	2
Figure 2	Viola – Jones Algorithm	4
Figure 3	VJ Algorithm Working	5
Figure 4	Haar-like features	6
Figure 5	Haar-like features found on image of face	6
Figure 6	Block Diagram	7
Figure 7	High level algorithm diagram	8
Figure 8	Viola – Jones Algorithm Test	9
Figure 9	Facial Landmarks	10
Figure 10	VJ Algorithm and Facial Landmarking	10
Figure 11	Eye Landmarks	11
Figure 12	Eye Landmarks (eyes closed)	12

CHAPTER 1

INTRODUCTION

A simplified distinction between passive and active safety systems in the automotive industry is that while the former mitigates the consequences of an accident, the latter prevent its occurrence. Discussed ahead are in brief, the main active safety systems which can be classified as Driver Assistance Systems (DAS) and Advanced DAS (ADAS).

1.1 HISTORY OF ADAS

Anti-lock braking systems (ABS) can be considered the first driver assistance systems introduced in the market, around 50 years ago. Simplifying, for their function it was sufficient just to measure one quantity, wheel speed, to consequently actuate a valve system in the braking circuit to prevent wheel blockage. For ADAS systems, 50 years later, sensors carry intelligence, and they do not only sense the vehicle state and its surroundings but also need to understand what they measure, and fuse these half-processed data with those from other sensors, which may use a different technology to compensate their own limits. Based on this perception layer, the systems then decide the correct action to be taken, and either inform/warn the driver or directly control the vehicle themselves.

The scenarios which must be covered include basically all of the situations the vehicle can encounter in its life: thousands of roads, traffic, and environmentally different conditions, which during development of such systems also need to be recorded and reconstructed for later debugging. This also

complicates the development process, which requires a huge amount of data logging and additional equipment fitted onboard vehicles.

Instead of analysing the different systems from a chronologic point of view, it is more useful to classify them based on the level of automation they guarantee, which has more impact on the sensors, redundancy and system architecture. The Society of Automotive Engineers (SAE) scale categorizes five levels of automated driving, as described in Fig. 1. There have been, and there are, DAS and ADAS on each level of automation.

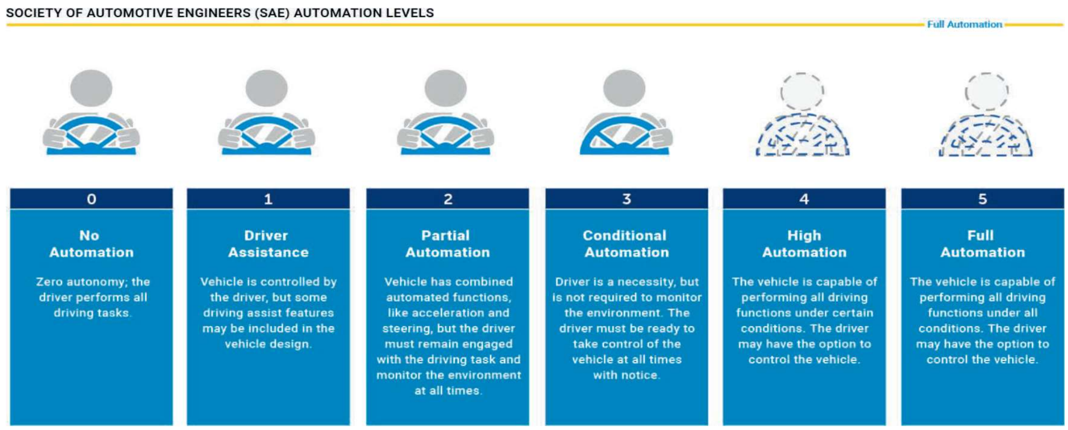


Figure 1: Society of Automotive Engineers (SAE) Automated Driving Levels

1.2 ADAS FOR DROWSINESS DETECTION

Human beings cause traffic accidents because they are distracted, drowsy, under psychotropic substances, or simply because they are poor drivers. Despite this, the human being is the best perception control system. Drowsiness prevents safe driving by reducing the driver's reaction speed, resulting in a 50% chance of causing death or serious injury in high-speed impacts.

Faced with this problem, Driver Assistance Systems (DAS) are developed, which help humans to maintain safe driving. The DAS inform the driver about the state of the vehicle and the environment, in addition, they warn the driver about possible risks that may affect the vehicle and itself. Within the DAS, there are, for example: driving stability, automatic parking, lateral control, traction control, anti-lock system, among others. In some operations, the DAS require complex processing to perform their functions, such as lane change control or lane-keeping support, this is how Advanced Driver Assistance Systems (ADAS, for its acronym) were developed.

In the future sections, we shall discuss the development and implementation of an ADAS, for the detection of driver drowsiness, using facial landmarks. The driver’s face and eyes position is used for detecting if driver is paying attention. Implemented algorithm is based on a Viola-Jones object detection framework. The algorithm is suitable because it can be implemented in a real-time fashion and was specially motivated by frontal face detection. It will not find a face if the driver is turned to the side. Moreover, after the face is found, facial landmarks are used to detect the eyes and find the Eye Aspect Ratio (EAR), a quantity which will help us analysis whether the driver is drowsy or not.

CHAPTER 2

SYSTEM ARRANGEMENT

2.1 CHOICE OF METHODOLOGY

Detection of driver's fatigue level represents one of the most researched topics when it comes to ADAS applications. In general, there are few different approaches:

1. **Measuring Heart Rate of the Driver:** Collecting data from a heart rate sensor attached to the driver. Then, a driver drowsiness detection algorithm based on heart rate variability (HRV) analysis and validates the proposed method by comparing with electroencephalography (EEG)-based sleep scoring. But, usage of such sensors too intrusive for real world use case.
2. **Vehicle Driving Patterns:** Driving patterns are based on monitoring of steering wheel movement, acceleration time series, or lane departure. But these are not very accurate as there are too many factors that can affect vehicle driving patterns and all these factors cannot be accounted for using an algorithm that has to run in real-time.
3. **Computer Vision techniques:** Computer vision techniques are more popular and focus on monitoring eye closure, yawning patterns, and generally analysing facial features and head movement. Techniques like template matching have the advantage of not being intrusive and easy to use, although a disadvantage is the lighting conditions. This disadvantage can also be solved by usage of IR cameras and other modern equipment in the field of imaging.

It is for this reason that usage of computer vision has been chosen for this prototype. For testing purposes, the prototype has been implemented in a controlled environment (well-lit room) and the algorithm developed to test the effectiveness of it.

2.2 WORKING PRINCIPLE

This method requires the usage of a few concepts, each of which are listed and described below.

2.2.1 THE VIOLA-JONES ALGORITHM

Developed in 2001 by Paul Viola and Michael Jones, the Viola-Jones algorithm is an object-recognition framework that allows the detection of image features in real-time. Despite being an outdated framework, Viola-Jones is quite powerful and its application has proven to be exceptionally notable in real-time face detection.

Viola-Jones was designed for frontal faces, so it is able to detect frontal the best rather than faces looking sideways, upwards or downwards. Before detecting a face, the image is converted into grayscale, since it is easier to work with and there's lesser data to process. The Viola-Jones algorithm first detects the face on the grayscale image and then finds the location on the coloured image.

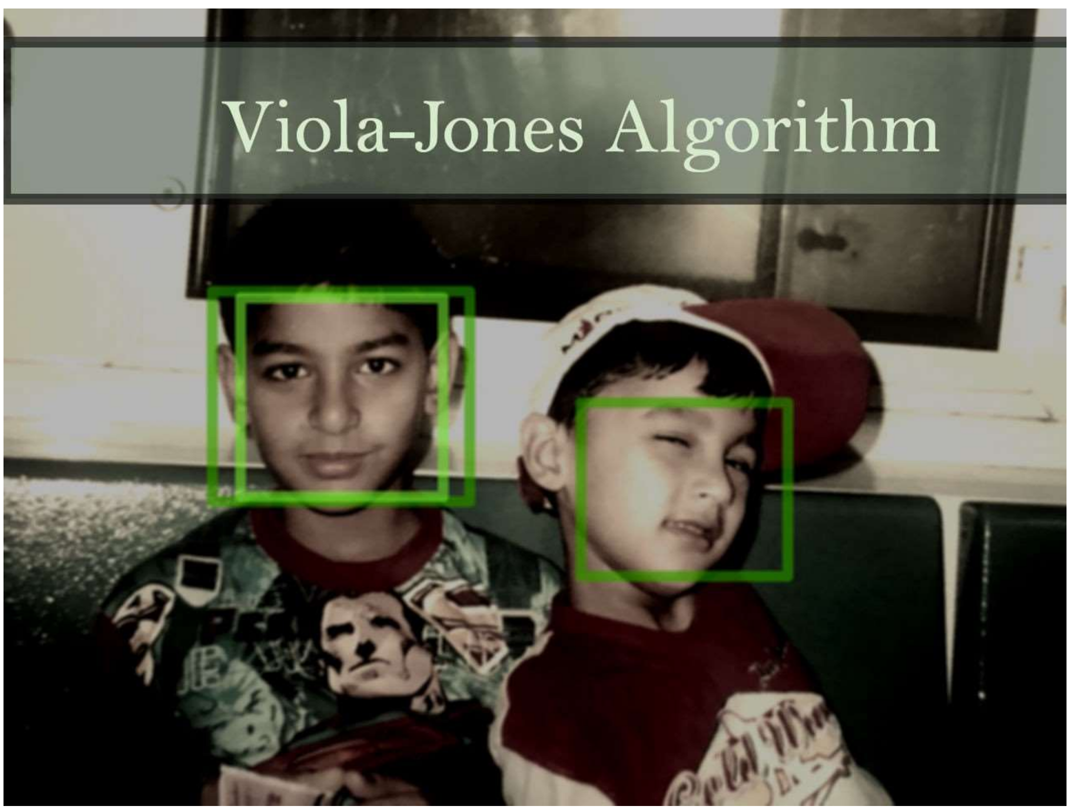


Figure 2: Viola-Jones Algorithm

Viola-Jones outlines a box, as shown in below Figure 3, and searches for a face within the box. It is essentially searching for these Haar-like features, which will be explained later. The box moves a step to the right after going through every tile in the picture. In this case, a large box size has been used and taken large steps for demonstration, but in general, you can change the box size and step size according to your needs.

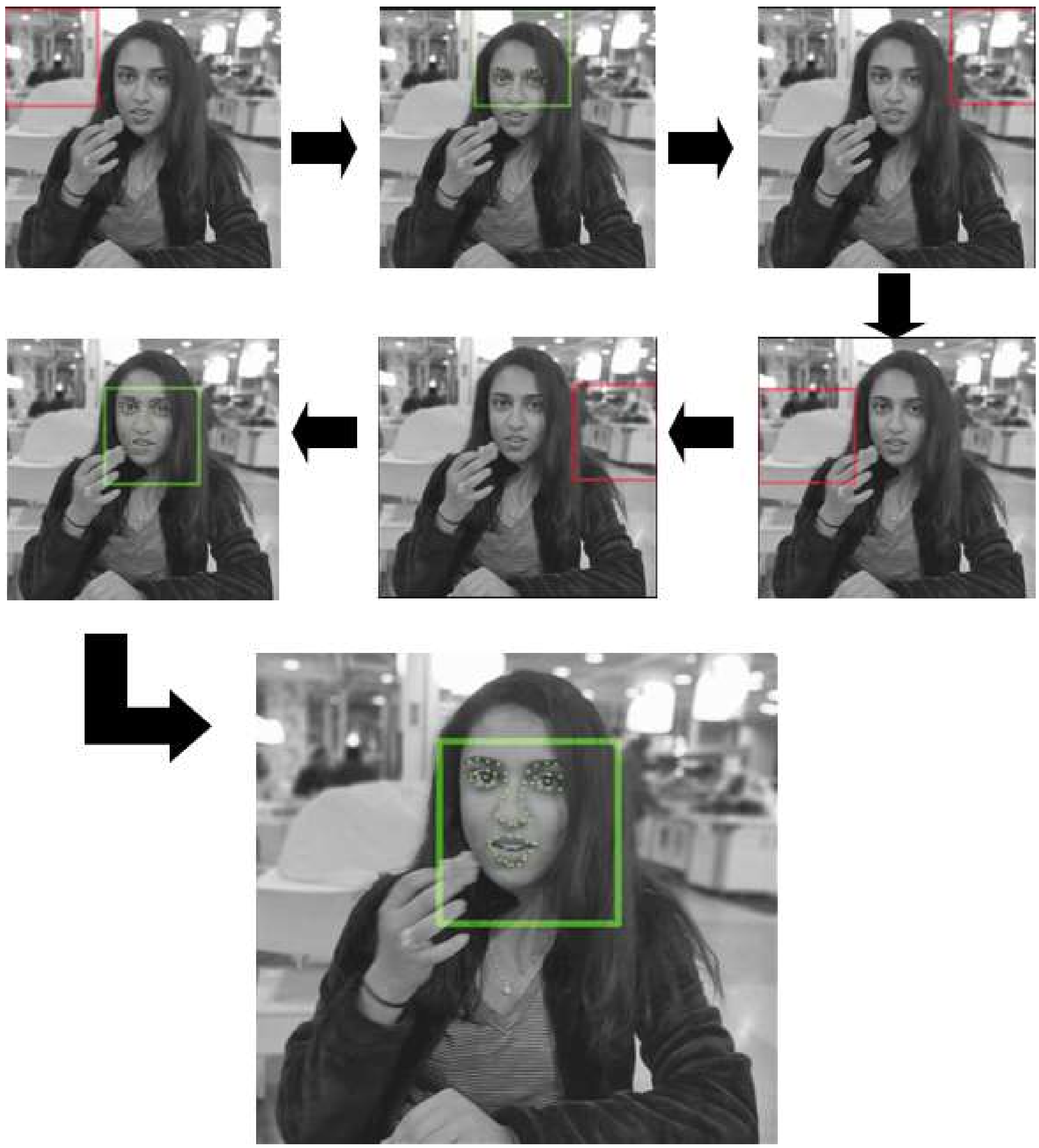


Figure 3: VJ Algorithm Working

With smaller steps, a number of boxes detect face-like features (Haar-like features) and the data of all of those boxes put together, helps the algorithm determine where the face is.

Haar-like features are named after Alfred Haar, a Hungarian mathematician in the 19th century who developed the concept of Haar wavelets (kind of like the ancestor of Haar-like features). The features below show a box with a light side and a dark side, which is how the machine determines what the feature is. Sometimes one side will be lighter than the other, as in an edge of an eyebrow. Sometimes the middle portion may be shinier than the surrounding boxes, which can be interpreted as a nose.

There are 3 types of Haar-like features that Viola and Jones identified in their research:

- Edge features
- Line features
- Four-Sided features

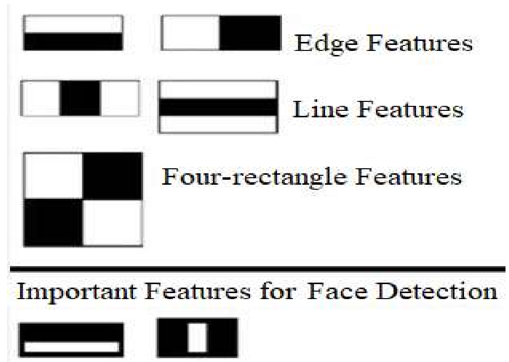


Figure 4: Haar-like features

These features help the machine understand what the image is. Imagine what the edge of a table would look like on a B&W image. One side will be lighter than the other, creating that edge like B&W feature as shown in above Figure 4.

In the two important features for Face Detection, the horizontal and the vertical features describe what eyebrows and the nose, respectively, look like to the machine.
Additionally, when the images are inspected, each feature has a value of its own. It's quite easy to calculate: Subtract White area from the Black area.

Figure 5: Haar-like features found on image of face

2.2.2 BLOCK DIAGRAM

The working block diagram of the system is shown in below figure 6.

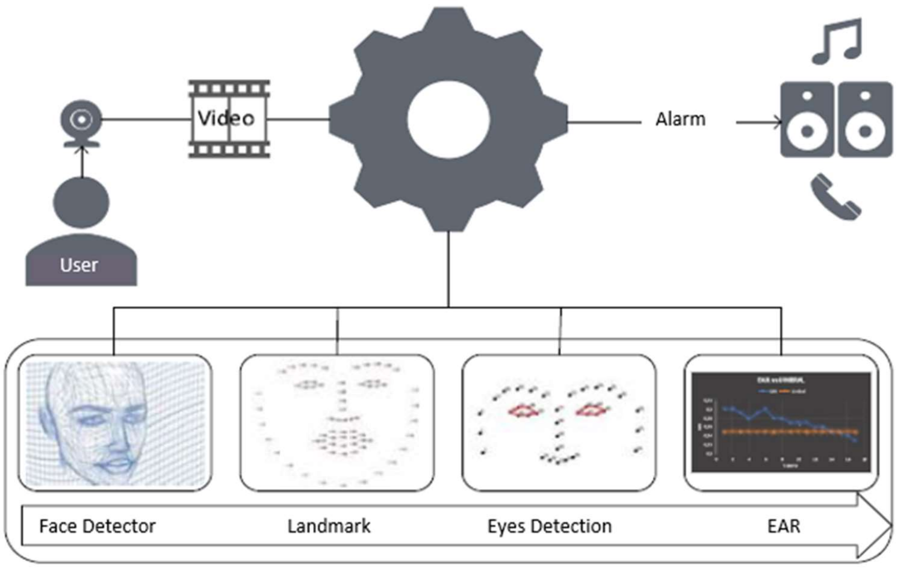


Figure 6: Block Diagram

For the development of the solution, it is proposed to use the Scrum methodology, which has an iterative and incremental project management method. Listed below are the various steps involved in the process:

- **Stage I:** The image is acquired through a webcam present in the testing apparatus.
- **Stage II:** The acquired image is now resized and converted to grayscale for further processing.
- **Stage III:** Now, the Viola-James Algorithm is applied to the image to find the exact location of the face in the image.
- **Stage IV:** Upon finding the face, strategies are applied to find the facial landmarks and detect the eyes of the face in the acquired image.
- **Stage V:** Once the eyes are found, an evaluation of the opening of the eye is carried out, to find the value of the Eye Aspect Ratio (EAR).
- **Stage VI:** Finally, the EAR value is evaluated with respect to the minimum threshold to find whether the driver is drowsy or not. If he/she is drowsy, an alarm will sound to alert the driver.

CHAPTER 3

METHODOLOGY

The implemented algorithm can be divided into the stages shown in Figure 7. stages “Grayscale & Crop” and “Resize” can be grouped into one phase – named “Input image pre-processing”. Those steps are shown separated in Figure 7. because it is important to see that resized image is input only for face detection (reasons will be given later).

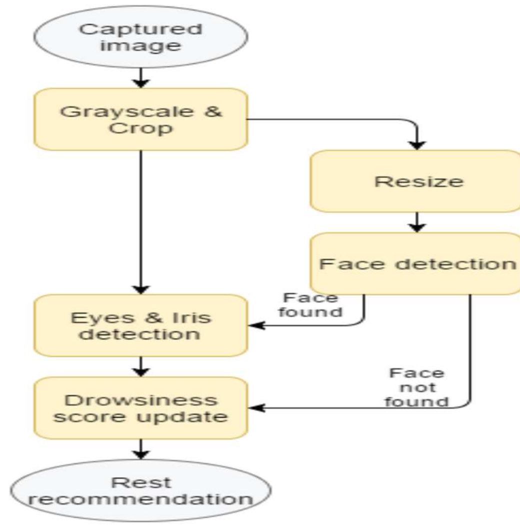


Figure 7: High level algorithm diagram

3.1 STAGE 1: IMAGE CAPTURE

The first stage is to capture the image of the person sitting in the driver’s seat. This is done by means of a camera that has been placed on the windshield of the car such that it can get a proper view of the driver’s face while not obstructing the driver’s field of view. For testing purposes, this experiment has been done in a controlled environment.

3.2 STAGE 2: IMAGE PRE-PROCESSING

In this stage, the image that was captured in the previous stage is taken and first converted to grayscale. This is done because the Viola – Jones Algorithm for face detection works only on black & white images. Next, the image resolution is reduced in order to speed up the execution. This won’t be much of a problem because a reduction in resolution does not affect the accuracy of the algorithm up to a certain limit. Finally, the image is cropped, whilst making the assumption that the face is in the centre of the image itself. The image is cropped in such a way that the face now covers about 35% of the image. This is the end of the image pre-processing stage.

3.3 STAGE 3: VIOLA – JONES ALGORITHM

Now that the image is ready, the Viola – Jones Algorithm (explained in section 2.2.1) is applied to the resultant image and the exact location of the face is detected. This is as shown in below figure 8.

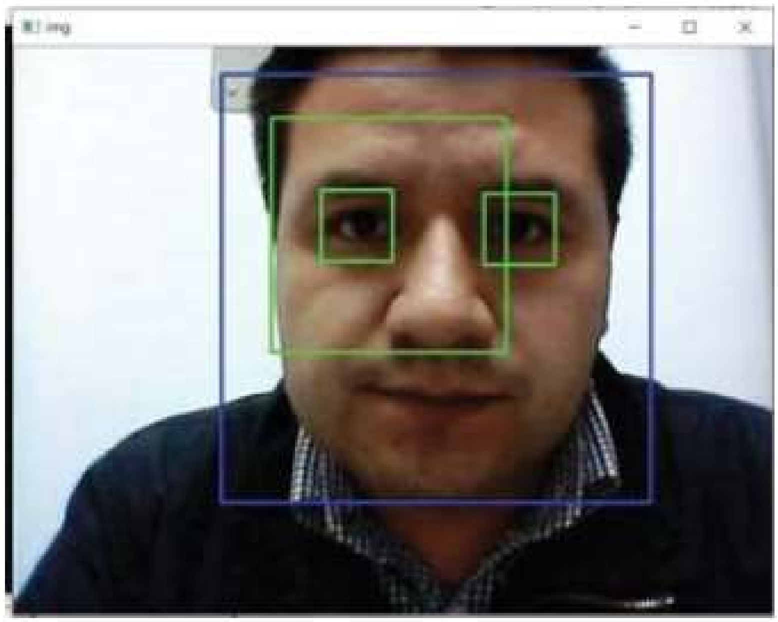


Figure 8: Viola – Jones Algorithm Test

As we can see, Figure 8 shows the result of testing a Haar Cascade algorithm for face detection, i.e., the Viola – Jones Algorithm, followed by a Haar Cascade algorithm for eye detection. On the other hand, when carrying out some tests with a webcam and an external camera, unsatisfactory results were obtained, possibly due to the variation of the light. In particular, the green squares should only locate the eyes, but has errors, therefore we chose to use facial landmarks.

3.4 STAGE 4: DETECTION OF FACIAL LANDMARKS

Facial landmarks are used to locate and represent prominent regions of the face, such as: eyes, eyebrows, nose, mouth.

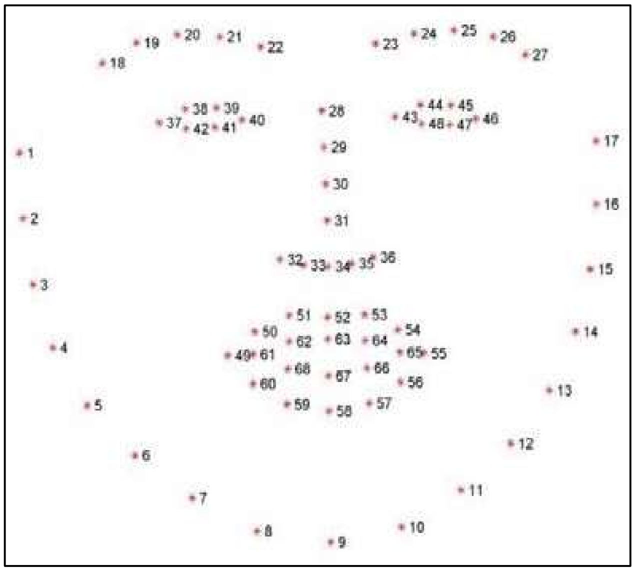
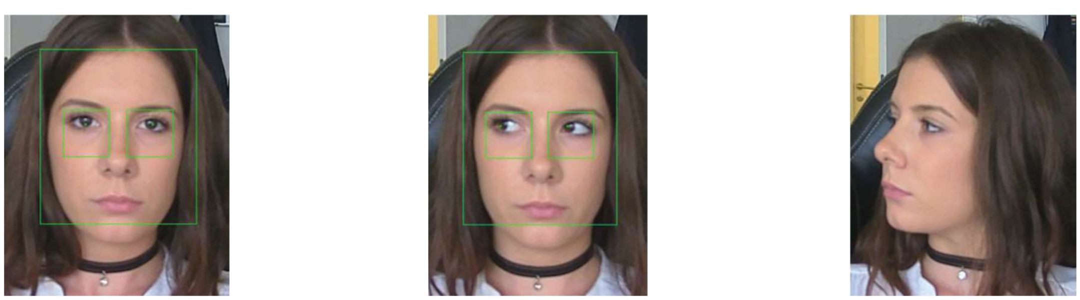


Figure 9: Facial Landmarks

Figure 9 shows the indices of the 68 coordinates (x, y) that are assigned to the facial structures on the face. Facial landmarks have been successfully applied to face alignment, head posture estimation, face swapping, blink detection, and much more. [12]. The pre-trained facial point detector within the dlib library is used to estimate the location of the 68 coordinates.

Upon finding all the facial landmarks correctly, the face and eyes can be detected with a good amount of accuracy. This is shown by the green squares outlining the face and eyes of the driver, as shown in below figure 10.



(a) **Driver looking at camera**

(b) **Driver's eyes are sideways**

(c) **Driver's face is sideways**

Figure 10: Viola – Jones Algorithm and facial landmarking result

Figure 10 (a) shows a case when a face is found, eyes are open and driver is looking ahead. Figure 10 (b) shows that the algorithm also works well in case when driver does not look ahead. It is natural for a driver to look left or right in order to check side mirrors or to address their attention to some other road event. It should be clear that drowsiness score should not rise in this case.

Figure 10 (c) shows a case when driver turns head to some side. In that case face detect algorithm will not find driver's face and that is sign that driver is not paying attention to the road. Not all rotations are sanctioned, whereas in this particular image head is completely turned right.

3.5 STAGE 5: EAR CALCULATION

By detecting facial landmarks, landmarks are extracted only from the eyes, as shown in below Figure 11. Each eye is represented by 6 (x, y) - coordinates, starting at the left corner of the eye, and then working clockwise around the rest of the region.

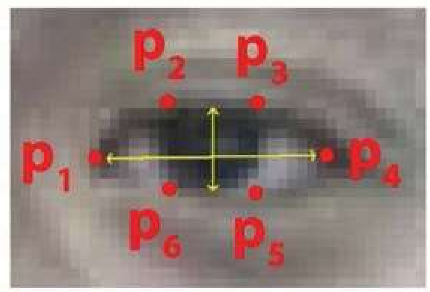


Figure 11: Eye Landmarks

There is a relationship between the width and the height of these coordinates. In an equation is derived that reflects the aspect ratio of the eye, known as the Eye Aspect Ratio (EAR). This equation is given below.

$$EAR = \frac{\|p2 - p6\| + \|p3 - p5\|}{2\|p1 - p4\|}$$

The EAR considers the distances between the various facial landmarks that describe the eye of the person and gives us a ratio that helps us to evaluate how much of the person's eye is open.

The lesser the EAR value, the more closed is the eye and the greater the EAR value, the more open is the eye. According to the results, limits of the EAR value can be determined to know if a person is drowsy.

3.6 STAGE 6: EAR EVALUATION

This is the final stage in the process. Upon calculating the EAR value, or the Drowsiness Score, it is placed between one of three intervals and that allows us to determine whether the person is feeling drowsy or not. The intervals in the acceptable range of values are as follows:

- 0-3 high
- 3-7 medium
- 7-10 low

A score in the high interval means that the driver is drowsy. If the driver is found to be drowsy, an alarm can be sounded to wake him/her up.

Thus, in this way, the six stages are carried out to find whether the driver is feeling drowsy or not. If he/she is feeling drowsy, then the drowsiness score allows the computer sitting in the car to evaluate how drowsy the person is. If the drowsiness score is below a value of 3, then an alarm can be sounded and the driver requested by the system to take a break from driving, as it is a matter of safety.

3.7 RESULTS

The results obtained by evaluating the detection of drowsiness using facial landmarks reflect an accuracy of 87%. The algorithm supports movements of the face and eyes in different ways without lowering the quality of its detection. Figure 12 shows the result of a person in a state of drowsiness, since it has an EAR index of 0.12, therefore, an alarm is activated to wake up the driver.

Figure 12: Eye landmarks (eyes closed)

CHAPTER 4

ADVANTAGES, DISADVANTAGES, APPLICATIONS AND FUTURE ENHANCEMENTS

4.1 ADVANTAGES

1. This model has an accuracy of up to 87% in detecting driver's drowsiness.
2. The algorithm supports movements of the face and eyes without lowering quality of detection.
3. It has almost immediate response, thus, ensuring that the driver can never get a chance to sleep and cause an accident.
4. It adds another dimension to ADAS systems.

4.2 DISADVANTAGES

1. This is an expensive system.
2. It requires some amount of calibration before it can be implemented in an automotive system.
3. Sometimes, the lighting in the car can be insufficient to allow detection of facial landmarks, thus causing the system failure.
4. It is yet under research & development.

4.3 APPLICATIONS & FUTURE ENHANCEMENTS

4.3.1 APPLICATIONS

As the title of this presentation suggests, the main application is in ADAS, but it may also be used in other vehicles.

4.3.2 FUTURE ENHANCEMENTS

1. Using infrared cameras would give better input images – we would have images with the same illumination level, so light would not be a factor.
2. Using advanced and more accurate methods for iris detection which are based on Bayesian classification of extracted features.
3. Integration with data coming from the car itself, like current speed, steering pattern etc.
4. Creating more sophisticated drowsiness score calculation scheme and testing it in actual vehicle.

CONCLUSION

The proposal for the development of an advanced driver assistance system for the detection of drowsiness is presented, where the algorithm based on facial reference points constitutes a given reference that supports the movements of the person.

Preliminary test results performed under various environmental conditions are satisfactory and reflect an accuracy of 87%.

The proposed system will allow detecting when a driver is drowsy, thus reducing the number of traffic accidents.

As future work, the drowsiness detection system will be implemented in a real environment inside a vehicle, in addition, the driver distraction detection will be implemented in real time.

REFERENCES

1. https://connect.bosch.com/blogs/bc09f0bf-9edd-4f5d-abc7-6a8f0f680c58/entry/ADAS_Advance_Driver_Assistance_Systems?lang=en_us

2. https://towardsdatascience.com/the-intuition-behind-facial-detection-the-viola-jones-algorithm-29d9106b6999

3. L. D. S. Cueva and J. Cordero, "Advanced Driver Assistance System for the drowsiness detection using facial landmarks," 2020 15th Iberian Conference on Information Systems and Technologies (CISTI), 2020, pp. 1-4, doi: 10.23919/CISTI49556.2020.9140893.

4. A. Simić, O. Kocić, M. Z. Bjelica and M. Milošević, "Driver monitoring algorithm for advanced driver assistance systems," 2016 24th Telecommunications Forum (TELFOR), 2016, pp. 1-4, doi: 10.1109/TELFOR.2016.7818908.

5. X. Zhao, E. Dellandrea, L. Chen and I. A. Kakadiaris, "Accurate Landmarking of Three-Dimensional Facial Data in the Presence of Facial Expressions and Occlusions Using a Three-Dimensional Statistical Facial Feature Model," in IEEE Transactions on Systems, Man, and Cybernetics, Part B (Cybernetics), vol. 41, no. 5, pp. 1417-1428, Oct. 2011, doi: 10.1109/TSMCB.2011.2148711.

6. A. Doshi, S. Y. Cheng and M. M. Trivedi, "A Novel Active Heads-Up Display for Driver Assistance," in IEEE Transactions on Systems, Man, and Cybernetics, Part B (Cybernetics), vol. 39, no. 1, pp. 85-93, Feb. 2009, doi: 10.1109/TSMCB.2008.923527.

7. K. Fujiwara et al., "Heart Rate Variability-Based Driver Drowsiness Detection and Its Validation With EEG," in IEEE Transactions on Biomedical Engineering, vol. 66, no. 6, pp. 1769-1778, June 2019, doi: 10.1109/TBME.2018.2879346.

8. M. Galvani, "History and future of driver assistance," in IEEE Instrumentation & Measurement Magazine, vol. 22, no. 1, pp. 11-16, Feb. 2019, doi: 10.1109/MIM.2019.8633345.

Sistema avanzado de asistencia al conductor para la detección de somnolencia utilizando puntos de referencia faciales

Advanced Driver Assistance System for the drowsiness detection using facial landmarks

Luis Darío Sinche Cueva
Departamento de Ciencias de la Computación
Universidad Técnica Particular de Loja
Loja, Ecuador
ldsinche@utpl.edu.ec

Jorge Cordero
Departamento de Ciencias de la Computación
Universidad Técnica Particular de Loja
Loja, Ecuador
jmcordero@utpl.edu.ec

Resumen — **En este trabajo se presenta el desarrollo de una solución para detectar la somnolencia de un conductor en tiempo real y emitir alertas para evitar posibles accidentes de tránsito. Particularmente, se realiza un análisis de los métodos usados para la detección de somnolencia mediante visión por computadora, centrándose en la utilización de puntos de referencia faciales. La distracción, somnolencia, el cansancio, el exceso de velocidad y la fatiga, son las principales causas de accidentes y, precisamente, los sistemas avanzados de asistencia al conductor contribuyen a reducir estos graves errores humanos.**

Palabras Clave – Puntos de referencia faciales; Vision por computadora; Detección de somnolencia.

Abstract — **This paper presents the development of a solution to detect a driver's drowsiness in real time and issue alerts to avoid possible traffic accidents. In particular, an analysis of the methods used for the detection of drowsiness by computer vision is performed, focusing on the use of facial reference points. Distraction, drowsiness, tiredness, speeding and fatigue are the main causes of accidents and, precisely, advanced driver assistance systems ADAS help reduce these serious human errors.**

Keywords – Facial landmark; Computer vision; Drowsiness Detection.

I. Introducción

Los seres humanos provocan accidentes de tránsito porque están distraídos, somnolientos, bajo sustancias psicotrópicas o por el simple hecho de ser malos conductores. A pesar de esto, el ser humano es el mejor sistema de control de percepción [1]. La somnolencia evita que la conducción sea segura, ya que reduce la velocidad de reacción del conductor, dando como resultado una probabilidad del 50% de causar muerte o lesiones graves en caso de impactos a alta velocidad [2].

Ante esta problemática, se desarrollan los Sistemas de Asistencia al Conductor (DAS), que ayudan al ser humano a mantener una conducción segura. Los DAS informan sobre el estado del vehículo y el entorno al conductor, además, advierten al conductor sobre posibles riesgos que puede afectar al vehículo y así mismo. Dentro de los DAS, se tiene, por ejemplo: estabilidad de conducción, estacionamiento automático, control lateral, control de tracción, sistema antibloqueo, entre otros. En algunas operaciones los DAS requieren de un procesamiento complejo para realizar sus funciones como en el caso del control de cambio de carril o el soporte para mantener el carril, es así que se desarrollan los Sistemas Avanzados de Asistencia al Conductor (ADAS, por sus siglas en inglés Advanced Driver Assistance System) [3].

En este artículo se describe el desarrollo e implementación de un ADAS, para la detección de somnolencia del conductor, utilizando puntos de referencia faciales. En la estructura del artículo, la sección II presenta los antecedentes que explican la problemática. En la sección III se describen estudios sobre métodos para la detección de somnolencia. La sección IV presenta la metodología y arquitectura del sistema. La sección V muestra los resultados preliminares. Finalmente, en la sección VI se describen las conclusiones y trabajos futuros.

II. Antecedentes

En Ecuador, en el año 2019, el número de accidentes fue de 24595, causando 19999 personas lesionadas y 2180 fallecidos [4]. Según las estadísticas, el número de vehículos matriculados creció el 7,4% entre el año 2017 y 2018, llegando a un total de 2.403.651 vehículos a nivel nacional. En el año 2018, el 24.13% de los accidentes se debe a conducir desatento a las condiciones de tránsito (celular, pantallas de video, comida, maquillaje o cualquier otro elemento distractor), y el 1.38% a conducir en estado de somnolencia o malas condiciones físicas (sueño, cansancio y fatiga) [5].

En la Tabla I se presenta los alarmantes valores de heridos y fallecidos, por año, a causa de los accidentes de tránsito en

Ecuador. Investigadores han puesto en marcha proyectos que permitan evitar accidentes de tránsito implementando ADAS.

TABLA I. ACCIDENTES EN EL PERIODO 2015-2019 EN ECUADOR

	2015	2016	2017	2018	2019
Accidentes	35.706	30.269	28.967	25.530	24.595
Heridos	25.234	21.458	22.018	19.858	19.999
Muertes	2.138	1.967	2.153	2.151	2.180

III. TRABAJOS RELACIONADOS

Existe en la literatura investigaciones que han desarrollado métodos para la detección de la somnolencia. Algunas han centrado sus estudios en analizar los rasgos faciales y el estado actual del conductor en tiempo real, para en caso de detectar fatiga, cansancio o somnolencia emitir alertas que permita al conductor establecer medidas de seguridad para sí mismo, para otros conductores y para los peatones, con el fin de evitar accidentes [6], [7].

En [8] se presentan tres categorías de medir la somnolencia del conductor, considerando patrones de conducción del vehículo, características psicológicas y técnicas de visión por computadora. Los patrones de conducción se basan en el monitoreo del movimiento del volante, series de tiempo de aceleración o salida de carril. Las técnicas que miden características psicológicas del conductor, se centran en bio-señales eléctricas como datos de Electroencefalografía (EEG), Electrocardiograma (ECG) y Electrooculograma (EOG) y ofrecen una precisión del 89.5% en detectar la somnolencia. Sin embargo, su desarrollo es menor debido a la intromisión de los diversos sensores que deben ser conectados al conductor. Por lo tanto, las técnicas de visión por computadora son más populares y se concentran en monitoreo del cierre de los ojos, los patrones de bostezo y en general analizar los rasgos faciales y movimiento de la cabeza.

En [9], los autores describen una revisión de las técnicas para detectar somnolencia, acentuando su análisis en las investigaciones basadas en visión por computadora: técnica de coincidencia de plantilla, parpadeo de ojos, PERCLOS y de bostezo. Estás técnicas de visión por computadora tienen la ventaja de no ser intrusivas y de fácil uso, aunque una desventaja son las condiciones de iluminación.

En [10], se propone un sistema que detecta la somnolencia y el cansancio de un ser humano, mediante el análisis de emociones utilizando redes neuronales convolucionales y seguimiento ocular. El sistema monitorea la actividad de la persona, es decir, el cambio de emoción, mediante una webcam y emite una alerta en caso de un comportamiento anormal.

El sistema propuesto en [11], mide el tiempo que los ojos están cerrados, y si lo están por más de 4 segundos, el sistema emitirá una alerta para advertir al conductor, al mismo tiempo emite una notificación (sms) del estado del conductor y su ubicación mediante GPS, a contacto designado para casos de emergencia. Este sistema es puesto a prueba con una cámara de celular y concluye que la distancia óptima entre la cámara y el conductor es entre 25 a 100 cm. Se determina también que la calidad de la imagen no debe ser tan alta para evitar atrasos en el procesamiento de imágenes y respuesta del algoritmo.

En [12], se crea un sistema de monitoreo de seguridad del conductor basado en IoT y visión por computador para predecir futuros riesgos. El sistema utiliza detectores de puntos de referencia faciales para detectar el marco de cara y ojos del conductor, cuando detecta somnolencia alerta y actualiza una base de datos del estado del conductor.

Las estadísticas indican la necesidad de sistemas confiable de detección de somnolencia que pueda alertar al conductor antes de que ocurra un accidente. En [13] se describe una revisión de literatura para determinar la somnolencia del conductor utilizando: (1) medidas basadas en el vehículo; (2) medidas de comportamiento y (3) medidas fisiológicas. Una revisión detallada de estas medidas proporcionará información sobre los sistemas actuales, los problemas asociados con ellos y las mejoras que deben hacerse para hacer un sistema robusto.

Muchas investigaciones han sido probadas en laboratorios y no en vehículos reales en movimiento, esto debido a la seguridad del conductor que tiene que estar en estado activo, en estado somnoliento y en estado distraído, con el sistema puesto a prueba, y puede ser muy peligroso. El inconveniente de realizar las pruebas en laboratorio, es que se omiten los retos que el medio ambiente y la carretera presentan, como la iluminación variable, el cambio de fondo y las vibraciones del vehículo [14]. En [15] se presenta un modelo industrial llamado “copilot”, que ha sido probado por conductores de camiones. Este sistema detecta los ojos y calcula el porcentaje de cierre del ojo para medir la somnolencia del conductor.

En este trabajo se presenta el desarrollo e implementación de un sistema avanzado de asistencia al conductor, para detectar en tiempo real la somnolencia del conductor, utilizando puntos de referencia faciales.

IV. METODOLOGÍA

Para el desarrollo de la solución, se propone usar la metodología Scrum, la cual posee un método de gestión de proyectos iterativo e incremental [16]. La arquitectura del sistema se presenta en la Figura 1, se inicia con la adquisición de imagen mediante la webcam. El procesamiento de la imagen comienza redimensionando la imagen y cambiándola a escala de grises. A continuación, se realiza la evaluación de la apertura del ojo, llegando a obtener el valor de la relación de aspecto del ojo (EAR, por sus siglas en inglés Eye Aspect Ratio). Finalmente se evalúa el parámetro obtenido de EAR con respecto al umbral mínimo permitido. Si el valor es menor durante cierto intervalo de tiempo la alarma sonará, caso contrario seguirá procesando continuamente el algoritmo.

A. *Detección por algoritmo de Viola & Jones*

Para la detección de la somnolencia, se pusieron a consideración los métodos más utilizados y precisos, como lo es el algoritmo de Viola & Jones [17]–[19]. Este algoritmo usa clasificadores en cascada basados en características Haar para la detección de objetos. La función en cascada se forma a partir de muchas imágenes positivas y negativas. Luego se usa para detectar objetos en otras imágenes [20].

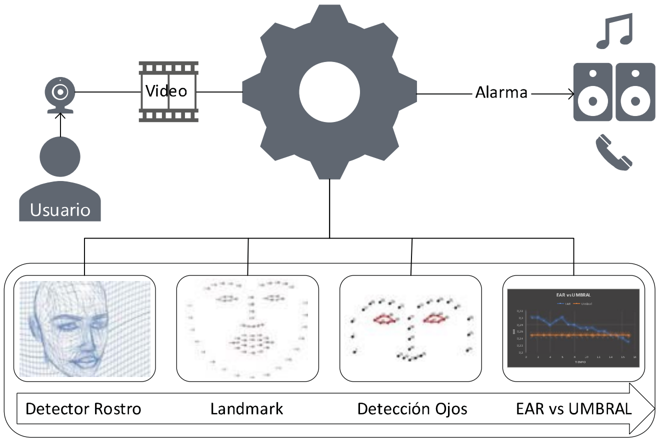


Figura 1. Arquitectura

En la Figura 2 se presenta el resultado de poner a prueba un algoritmo HaarCascade para la detección de rostro, seguido de un algoritmo HaarCascade para la detección de ojos. Por otra parte, al realizar algunas pruebas con una webcam y una cámara externa, se obtuvo resultados insatisfactorios, posiblemente a la variación de la luz. Particularmente, los recuadros verdes deberían ubicar únicamente los ojos, pero presenta errores, por lo tanto, se optó por utilizar puntos de referencia faciales.

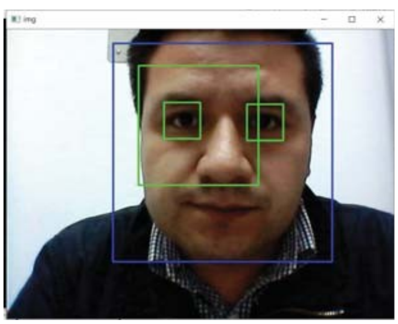


Figura 2. Prueba del algoritmo Viola & Jones

B. *Detección de puntos de referencia faciales*

Los puntos de referencia faciales se utilizan para localizar y representar regiones sobresalientes de la cara, tales como: ojos, cejas, nariz, boca.

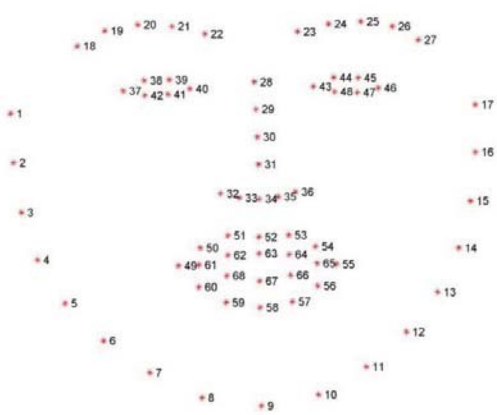


Figura 3. Puntos de referencia faciales [21]

En la Figura 3 se visualizan los índices de las 68 coordenadas (x, y) que se asignan a las estructuras faciales en la cara. Los puntos de referencia faciales se han aplicado con éxito a la alineación de rostros, la estimación de la postura de la cabeza, el intercambio de rostros, la detección de parpadeo y mucho más. [12]. El detector de puntos faciales pre-entrenado dentro de la biblioteca dlib se usa para estimar la ubicación de las 68 coordenadas.

C. *Detección de ojos*

Mediante la detección de puntos de referencia faciales, se extrae los puntos de referencia únicamente de los ojos (ver Figura 4). Cada ojo está representado por 6 (x, y) -coordinadas, comenzando en la esquina izquierda del ojo, y luego trabajando en sentido horario alrededor del resto de la región [22].

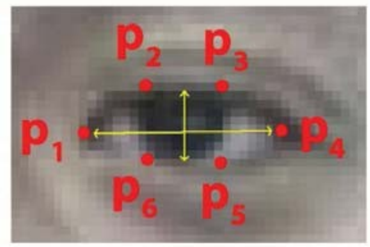


Figura 4. Puntos de referencia del ojo [21]

Existe una relación entre el ancho y el alto de estas coordenadas. En [22] se deriva una ecuación que refleja la relación de aspecto del ojo EAR. De acuerdo con los resultados se puede determinar límites del valor EAR para saber si una persona esta somnolienta.

$$EAR = \frac{\|p2-p6\|+\|p3-p5\|}{2\|p1-p4\|} \quad (1)$$

D. *Evaluación de algoritmos*

Para la evaluación de los algoritmos. Los algoritmos fueron implementados y evaluados en Python 3.6, para ello fue necesario implementar varias bibliotecas como OpenCV e imutils. Además, para la edición del código se utilizó Visual studio code.

El sistema fue desarrollado en una laptop Asus i7. La webcam incorporada trabajo al mismo nivel que una cámara ActiView, es decir, ambas dieron los mismos resultados.

El ambiente de trabajo fue en un salón de estudio, a diversas horas del día, pero manteniendo un ambiente luminoso casi regular, aunque con la cámara ActiView la intensidad de luminosidad aumentaba, los resultados seguían siendo los mismos. Se espera poner a prueba el sistema en un ambiente externo dentro de un vehículo a distintas horas del día y evaluar los resultados.

V. RESULTADOS PRELIMINARES

Los resultados obtenidos evaluando la detección de somnolencia mediante puntos de referencia faciales reflejan una precisión del 87%. El algoritmo soporta movimientos del rostro y de los ojos de distintas formas sin bajar la calidad de su detección. En la Figura 5 se observa el resultado de una persona en un estado de somnolencia, dado que presenta un índice EAR de 0.12, por lo tanto, se activa una la alarma para despertar al conductor.

Figura 5. Puntos de referencia del ojo

VI. CONCLUSIONES

Se presenta la propuesta de desarrollo de un sistema avanzado de asistencia al conductor para la detección de somnolencia, donde el algoritmo basado en puntos de referencia faciales constituye un referente dado soporta los movimientos de la persona.

Los resultados de las pruebas preliminares realizadas en varias condiciones ambientales, son satisfactorios y reflejan una precisión del 87%.

El sistema propuesto permitirá detectar cuando un conductor esta somnoliento, de esta forma se podrá reducir el número de accidentes de tránsito.

Como trabajo futuro se implementará el sistema de detección de somnolencia en un ambiente real dentro de un vehículo, además, se implementará la detección de distracción del conductor en tiempo real.

REFERÊNCIAS BIBLIOGRÁFICA

[1] WHO, "Driver Fatigue and Road Accidents Factsheet," *R. Soc. Prev. Accid.*, vol. Registered, no. August, pp. 3–5, 2017.

[2] L. Fridman *et al.*, "MIT Autonomous Vehicle Technology Study: Large-Scale Deep Learning Based Analysis of Driver Behavior and Interaction with Automation," vol. 6, pp. 1–17, 2017.

[3] M. Zhao, "Advanced Driver Assistant System: Theats, Requirements and Security Solutions," *Tech. White Pap.*, pp. 1–36, 2016.

[4] Agencia Nacional de Tránsito, "Descargables - Accidentes2015 - Agencia Nacional de Tránsito del Ecuador - ANT," *Agencia Nacional de Tránsito*, 2015. .

[5] INEC, "Estadísticas de Transporte," 2019. .

[6] J. Goncalves, E. Silva, and V. Carvalho, "Detection of sleep disturbances for road prevention," in *2018 13th Iberian Conference on Information Systems and Technologies (CISTI)*, 2018, pp. 1–4.

[7] K. Małecki, A. Nowosielski, and P. Forczmański, "Multispectral data acquisition in the assessment of driver's fatigue," in *International Conference on Transport Systems Telematics*, 2017, pp. 320–332.

[8] B. Reddy, Y. H. Kim, S. Yun, C. Seo, and J. Jang, "Real-Time Driver Drowsiness Detection for Embedded System Using Model Compression of Deep Neural Networks," *IEEE Comput. Soc. Conf. Comput. Vis. Pattern Recognit. Work.*, vol. 2017-July, pp. 438–445, 2017, doi: 10.1109/CVPRW.2017.59.

[9] M. Rizwan, M. Aslam, M. Imran, and M.-E. A. Maria, *Driver's Drowsiness Detection Through Computer Vision: A Review*, vol. 164. Springer International Publishing, 2015.

[10] S. Nandyala, G. K, C. Bhushan, V. Gandi, and M. Manalikandy, "Emotion Analytics for Advanced Driver Monitoring System," *SAE Tech. Pap. Ser.*, vol. 1, 2019, doi: 10.4271/2019-26-0025.

[11] A. Syahirah, A. Bakar, G. K. Shan, G. L. Ta, and R. A. Karim, *Proceedings of the 10th National Technical Seminar on Underwater System Technology 2018*, vol. 538. Springer Singapore, 2019.

[12] S. E. Shan, M. F. Faisal, S. Rezaul Haque, and P. Saha, "IoT and Computer Vision Based Driver Safety Monitoring System with Risk Prediction," *Int. Conf. Comput. Commun. Chem. Mater. Electron. Eng. IC4ME2 2018*, pp. 1–4, 2018, doi: 10.1109/IC4ME2.2018.8465617.

[13] A. Sahayadhas, K. Sundaraj, and M. Murugappan, "Detecting driver drowsiness based on sensors: a review," *Sensors*, vol. 12, no. 12, pp. 16937–16953, 2012.

[14] L. C. Jain, S. Patnaik, and N. Ichalkaranje, "Intelligent computing, communication and devices: Proceedings of ICCD 2014, volume 1," *Adv. Intell. Syst. Comput.*, vol. 308 AISC, no. VOLUME 1, pp. 737–743, 2015, doi: 10.1007/978-81-322-2012-1.

[15] R. Grace and S. Steward, "Drowsy Driver Monitor and Warning System," no. August, pp. 64–69, 2017, doi: 10.17077/drivingassessment.1010.

[16] K. Schwaber and J. Sutherland, "La guía de Scrum," *Scrumguides. Org*, vol. 1, p. 21, 2013.

[17] Y.-Q. Wang, "An analysis of the Viola-Jones face detection algorithm," *Image Process. Line*, vol. 4, pp. 128–148, 2014.

[18] D. C. Salazar, H. G. Alvarado, C. B. G. Maldonado, and L. Lanzarini, "Object detection application and Viola Jones algorithm for the development of a database in Alzheimer's patients," in *2019 14th Iberian Conference on Information Systems and Technologies (CISTI)*, pp. 1–7.

[19] M. Kahlon and S. Ganesan, "Driver Drowsiness Detection System Based on Binary Eyes Image Data," in *2018 IEEE International Conference on Electro/Information Technology (EIT)*, 2018, pp. 209–215.

[20] "OpenCV: Cascade Classifier." .

[21] M. Oh, Y. Jeong, and K.-H. Park, "Driver Drowsiness Detection Algorithm based on Facial Features," *J. Korea Multimed. Soc.*, vol. 19, no. 11, pp. 1852–1861, 2016, doi: 10.9717/kmms.2016.19.11.1852.

[22] T. Soukupova and J. Cech, "Real-Time Eye Blink Detection using Facial Landmarks," *Cent. Mach. Perception, Dep. Cybern. Fac. Electr. Eng. Czech Tech. Univ. Prague*, pp. 1–8, 2016, doi: 10.1017/CBO9781107415324.004.

Driver monitoring algorithm for Advanced Driver Assistance Systems

Aleksandra Simić, Ognjen Kocić, Milan Z. Bjelica and Milena Milošević

Abstract **—Fast expansion of Advanced Driver Assistance Systems (ADAS) market and applications has resulted in a high demand for various accompanying algorithms. In this paper we present an implementation of Driver monitoring algorithm. Main goal of the algorithm is to automatically asses if driver is tired and in that case, raise a proper alert. It is widely used as a standard component of rest recommendation systems. Our approach is based on combination of computer vision algorithms for face detection and eyes detection. Additionally, we have tested our implementation in controlled environment on a real ADAS platform board.**

Keywords **— Advanced Driver Assistance Systems, driver monitoring, eyelid detection, face detection**

I. Introduction

MAIN goal of Advance Driver Assistance System (ADAS) is to provide safer environment for driver and to contribute to traffic safety in general. ADAS is constantly providing new solutions for non-trivial real world problems like automated freeway driving, which is addressed by lane detection algorithm [1], pedestrian detection [2], road signs recognition [3], automated parking [4], driver fatigue detection [5] and many more. Driver monitoring has a special place among these algorithms, as it is addressing the driver's fatigue problem, which is responsible for serious number of road accidents.

This paper provides detailed description of an algorithm design and implementation for the aforementioned driver monitoring. Driver's face and eyes position are used for detecting if driver is paying attention. Implemented algorithm is based on a Viola-Jones object detection framework (2001) [6]. The algorithm is suitable because it can be implemented in a real-time fashion and was specially motivated by frontal face detection. It will not found a face if the driver is turned to the side. Moreover, after the face was found, eye center detection algorithm is implemented using common face proportions (to locate the eyes region) and weighted matrix sum (to detect the iris).

Aleksandra Simić is with the Faculty of Mathematics, University of Belgrade, Studentski Trg 16, 11000 Belgrade, Serbia (phone: 381-65-3835662; e-mail: asimic@matf.bg.ac.rs).

Ognjen Kocić is with the Faculty of Mathematics, University of Belgrade, Studentski Trg 16, 11000 Belgrade, Serbia (phone: 381-65-2235055; e-mail: ognjen@matf.bg.ac.rs).

Dr. Milan Bjelica is with the Department of Computer Engineering and Communications, Faculty of Technical Sciences, 21000 Novi Sad, Serbia (email: milan.bjelica@rt-rk.com)

Milena Miloševic is with RT-RK Institute for Computer Based Systems, Novi Sad, Serbia (email: milena.milosevic@rt-rk.com)

II. Related work

Detection of driver's fatigue level represents one of the most researched topics when it comes to ADAS applications [5]. In general, there are few different approaches. First one combines readings from multiple sensors that are attached to driver. Conclusions are drawn using a fusion of collected data. For example, researchers have used heart rate measurements for this purpose [7].

Some may found usage of sensors too intrusive for real world use case. As often used alternative, driver is recorded with some camera equipment and computer vision algorithms are applied in order to detect where the driver is looking and if he/she pays attention to the road. Solution described in this paper can be classified into this group.

Additionally, there are methods that consider driving patterns as a main indicator of driver tiredness [8].

Finally, it might be important to note one major difference between these approaches. When detecting long term drowsiness it is more suitable to use sensor or pattern methods. However, if we are trying to prevent accident that might occur as a result of imminent distraction, computer vision based methods are proven to be more beneficial.

III. Algorithm implementation

The implemented algorithm can be divided into few phases. These phases and their connections are shown in Fig. 1.

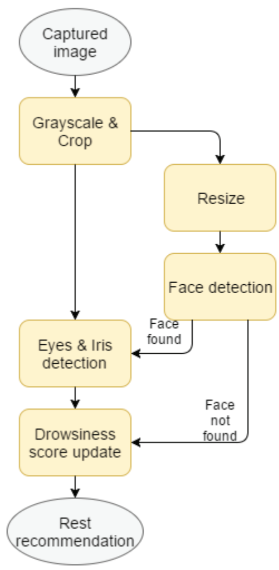


Fig. 1. High level algorithm diagram

978-1-5090-4086-5/16/$31.00 ©2016 IEEE

Phases "Grayscale & Crop" and "Resize" can be grouped into one phase – named "Input image preprocessing". Those steps are shown separated in Fig.1. because it is important to see that resized image is input only for face detection (reasons will be given later).

A. Input Image preprocessing

Firstly, BGRA frame that is produced by camera is converted to grayscale. The reason for doing this is because a grayscale image is a requirement for Viola Jones algorithm for face detection (described in phase B) and it is also well suitable for iris detection.

Besides that, we took advantage of the fact that we need to detect only one face, which by assumption occupies large area in center of input frame. Since face should be centered, we cropped 35% of frame's width, because we do not want to preprocess and later analyze parts of image where there is no chance for face or eyes to be found. As the result of these simple preprocessing steps, image that is suitable for eyes and iris detection was successfully formed.

It is already mentioned that we search for a very large face. Having that in mind, we concluded that input image can be downscaled in purpose of getting face detection algorithm that works faster and achieves the same accuracy. This cannot be applied for eyes and iris detection because iris occupies only small portion of image and working with small image would damage detection quality.

B. Face detection

VJ framework can be divided in two phases. First phase is a preparation phase and it consists from *Haar feature selection* and *AdaBoost* training, while second is a face detection phase. Haar features can be thought of as convenient rectangle shaped filters (shown on Fig. below).

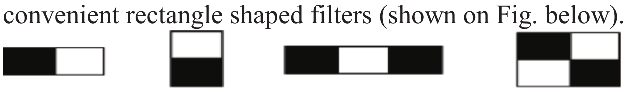


Fig. 2. Haar features

It was observed by Viola and Jones that the grayscale image of human face has some special characteristics. For example, eye region of image is darker than the rest. Furthermore, vertical nose region is distinctively brighter. Filters shown in Fig. 2. are applied to a face image and sums of pixels in brighter regions of rectangles are subtracted from the dark ones. Given value is then compared to some threshold which is used to determine if current region is the region we are interested in. Some observations to be made are that there are 2 types of two-rectangle features, 2 types of three-rectangle features and a single type of four-rectangle features (considering symmetry in our deduction process). Smallest rectangle for first feature left to right from Fig. 2. is 1x2 pixels and because of that width must be an even number, which also stands for height of the second feature. Similarly, for third feature left to right, width must be divisible by 3. When listed limitations for described features are included and 24x24 pixels base filter (it is standard detection window size) is used, there is about 160K features which is too much for a real time application to examine. *AdaBoost* training is used to select the best features that will provide the most information about scanned part of image. As a result of the first phase, complete set of features that will be used for face detection is determined. First phase can be done only one time, whereas we can run face detection using that data many times. In general, this is a good approach since there are no performance penalties in actual face detection that are related to preparation phase of the algorithm. After features are selected, they shall be applied to the image.

In general, on a single image one can expect human faces in many sizes. For example, one face may fit in a 50x50 pixels bounding rectangle, while other might be better placed in 30x30 pixels bounding rectangle. If the standard detection window of 24x24 pixels is used, it is not difficult to see that some faces might not fit into it. Because of that, feature detection is run on an image pyramid with intuition that at some level in pyramid both faces will fit into 24x24 rectangle (of course not at the same level). Image pyramid consists of sequence of images down sized by some factor. Pseudo-code is given as follows:

```
for each image in image pyramid do
 compute integral and squared integral image
 for each position of sliding detection window do
  for each stage in cascade classifier do
   initialize score for this stage
   for each feature in stage do
    apply filter to detection rectangle region of image
    update stage score
   done
   if stage score < threshold do
    reject rectangle region
    break two loops
   done
  done
  accept rectangle of interest
 done
done
```

Fig. 3. Face detection pseudo-code

Output of this algorithm is an array of rectangles that represent founded faces. It is possible that one face is founded in more than one phase (more than one image in image pyramid). Because of that, we need to group all rectangles that have at least 65% overlapping, which was determined empirically.

Finally, even after this step, more than one face can be found (for example someone can watch the road over the driver's shoulder). In that case, the rectangle that is closest to the image center is chosen.

Output of face detection phase is one rectangle that represents driver's face, if the face was found or invalid rectangle otherwise.

C. Eyes and iris detection

First step of eyes center detection algorithm is to crop input image to already detected face rectangle. Standard biometric proportions are then applied to further reduce processing to rectangles that contain only left and right eye. These proportions are shown in Fig. 4. Blue rectangle represents face whereas green rectangles represent eye regions.

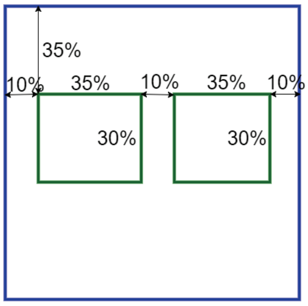


Fig. 4. Biometric proportions

These regions are input to iris detection phase. We used a fact that iris is darker then sclera around it and we developed a custom algorithm that uses weighted matrix sums. Matrix used can be thought of as some kind of convolution kernel. It is populated with floating point values that are concentrically reduced by factor k from inside out. An example is shown in Fig. 5.

1	1	1	1	1	1	1
1	1.25	1.25	1.25	1.25	1.25	1
1	1.25	1.56	1.56	1.56	1.25	1
1	1.25	1.56	1.95	1.56	1.25	1
1	1.25	1.56	1.56	1.56	1.25	1
1	1.25	1.25	1.25	1.25	1.25	1
1	1	1	1	1	1	1

Fig. 5 Weight matrix, k=1.25, dimension = 7

Matrix dimension must be odd number and it depends on eye region size. Coefficient k, used to calculate matrix values, is empirically determined value. Before applying this matrix on surroundings of each pixel, we have done one more matrix modification - normalization. This means that we have divided each element of matrix with sum of initial matrix that is not normalized (Fig. 6). Total sum of all coefficients in normalized matrix equals 1.

0.0171	0.0171	0.0171	0.0171	0.0171	0.0171	0.0171
0.0171	0.0214	0.0214	0.0214	0.0214	0.0214	0.0171
0.0171	0.0214	0.0267	0.0267	0.0267	0.0214	0.0171
0.0171	0.0214	0.0267	0.0334	0.0267	0.0214	0.0171
0.0171	0.0214	0.0267	0.0267	0.0267	0.0214	0.0171
0.0171	0.0214	0.0214	0.0214	0.0214	0.0214	0.0171
0.0171	0.0171	0.0171	0.0171	0.0171	0.0171	0.0171

Fig. 6. Normalized weight matrix (from Fig.5.)

For each considered pixel, weighted sum of its ambience is calculated. When whole image has been processed, iris should contain pixel for which the sum was minimal. Intuition behind algorithm is that we want to punish more bright pixels near center of applied filter, then pixels on the edge of filter. Moreover, these punishments should happen gradually because of fact that neighbor pixels are also very important for correctness of algorithm.

When center of eye is determined, next task is to deduce if eye is opened or closed. Again, our approach was associated with weight matrices. Let's consider grayscale image of closed eye for a moment. In the center of this image we have a strong line of dark values that correspond to eyelashes. However, when eye is opened, such line cannot be established (Fig. 7). With this distinction to guide us, we constructed another weight matrix with values vertically progressing from center of matrix to the top and bottom. It should be clear that this matrix is applied on top of eye center pixel which lies in middle (Fig. 8). Additionally, matrix width is reduced by 50% (25% on each side) in order to eliminate border noise (Fig. 8). As well as previously presented concentric matrix, this matrix was also normalized.

Fig. 7. (a) Eye close (b) Eye open

Finally, a criterion if eye is open was formed by comparing quotient of average pixel value in region of interest and weighted matrix sum against the threshold. This threshold was established after series of experiments.

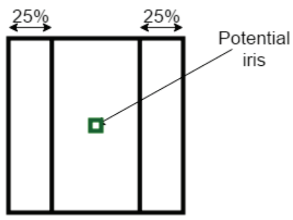


Fig. 8. Second weighted matrix position

D. Drowsiness score calculation

Final phase of described algorithm is calculation of drowsiness score. Drowsiness score is value in range between 0 and 10. This range is divided into three intervals:

- 0-3 low
- 3-7 medium
- 7-10 high

New score is calculated based on previous score *PrevScore* and output of face and eye detect phases for current frame.

Difference between intervals is:

- If *PrevScore* is in low interval, then score twice faster decreases than it rises
- If *PrevScore* is in medium interval, then score decreases and rises at the same rate
- If *PrevScore* is in high interval, then score twice faster rises, than it decreases

When score is in low interval, we can tell that driver is not distracted at all. In case of medium and high score, driver is drowsy and system should eventually alert the driver.

IV. Evaluation

Described algorithm gives the best results if camera and light source are placed in front of the driver. Algorithm output used for verification of detected regions is shown in Fig. 9.

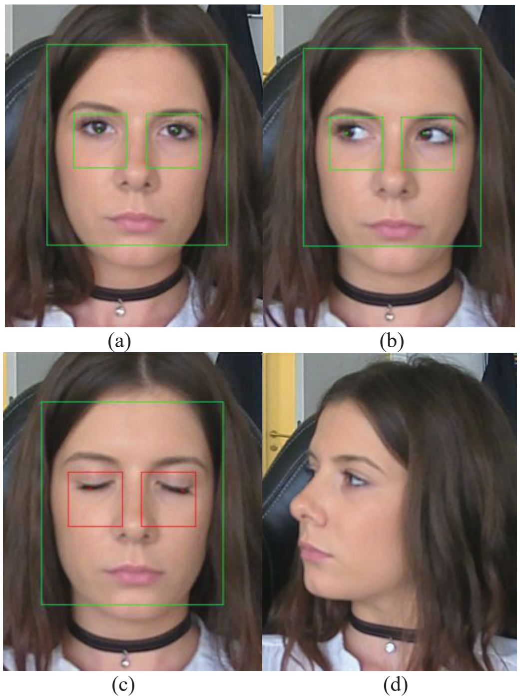


Fig. 9. Algorithm output examples

Image (a) shows a case when a face is found, eyes are open and driver is looking ahead. In this case, drowsiness score is decreasing depending on its current value.

Image (b) shows that our algorithm also works well in case when driver does not look ahead. It is natural for a driver to look left or right in order to check side mirrors or to address their attention to some other road event. It should be clear that drowsiness score should not rise in this case.

Image (c) shows driver with closed eyes and red rectangle shows that algorithm detected that eyes are not opened. This may be a serious problem if driver is sleeping. However, it may be the case that camera took the frame when they were blinking. No matter what happened drowsiness score will rise.

Image (d) shows case when driver turns head to some side. In that case face detect algorithm will not find driver's face and that is sign that driver is not paying attention to the road. Not all rotations are sanctioned, whereas in this particular image head is completely turned right. Of course, score that measures distraction will increase.

The algorithm was tested on real ADAS platform board. It works as real-time algorithm (about 20 frames per second) with high level of accuracy. The main reason for good driver monitoring performance is minimal impact of wrongly classified frames due to high framerate and the manner of drowsiness score calculation. The algorithm was implemented only for demo purposes and detailed statistical evaluation will be part of future work.

The algorithm was not tested at night because it requires infrared cameras which were not available at the time.

V. Conclusion

In this paper we described one implementation of driver monitoring algorithm, which is in early stage of development. Implemented algorithm is not state of the art, but we have achieved some solid results. There is more than one way we can improve this algorithm:

- Using infrared cameras would give better input images – we would have images with the same illumination level, so light would not be a factor.
- Using advanced and more accurate methods for iris detection which are based on Bayesian classification of extracted features.
- Integration with data coming from the car itself, like current speed, steering pattern etc.
- Creating more sophisticated drowsiness score calculation scheme and testing it in actual vehicle.

First two ideas do not require usage of additional equipment. Consequently, working on these ideas will be our first step. Upon successful completion of these steps, further refinements can be implemented during the in car testing.

Acknowledgment

This work was partially supported by the Ministry of Education, Science and Technological Development of the Republic of Serbia, under grant number: TR32041.

References

[1] M. Aly, "Real time Detection of Lane Markers in Urban Streets" in *IEEE Intelligent Vehicles Symposium, Eindhoven, The Netherlands, June 2008*

[2] P. Dollar, C. Wojek, B. Schiele, and P. Perona, "Pedestrian Detection: An Evaluation of the State of the Art" in *IEEE Transactions on Pattern Analysis and Machine Intelligence (Volume: 34, Issue: 4, April 2012)*

[3] S. Hossain, Z. Hyder, "Traffic Road Sign Detection and Recognition for Automotive Vehicles" in *International Journal of Computer Applications,* Volume 120 - Number 24, 2015

[4] H. Al-Absi, J. Devaraj, P. Sebastian, V. Yap, "Vision-based automated parking system" in *10th International Conference on Information Sciences Signal Processing and their Applications (ISSPA),* 2010

[5] Hang-Bong Kang, "Various Approaches for Driver and Driving Behavior Monitoring: A Review" in *Computer Vision Workshops (ICCVW), 2013 IEEE International Conference*, 2-8 Dec. 2013.

[6] P. Viola, M. Jones, "Rapid object detection using a boosted cascade of simple features" in *Computer Vision and Pattern Recognition, 2001. CVPR 2001.*

[7] J. Vicente, P. Laguna, A. Bartra, R. Bailón, "Drowsiness detection using heart rate variability" in *Medical & Biological Engineering & Computing,* June 2016, Volume 54, Issue 6, pp 927–937

[8] J. Kim, S. Kim, H. Jung, B. Lee, E. Chung, "Driver's Drowsiness Warning System Based on Analyzing Driving Patterns and Facial Images" in *23rd International Technical Conference on the Enhanced Safety of Vehicles (ESV*), 2013