Universidad Politécnica de Madrid

Escuela Técnica Superior de Ingenieros Industriales

Máster en Automática y Robótica

Computer Vision

Driving Drowsiness Detection - 2^{nd} Delivery

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DELIVERY 2

Technology Exploration Report. Specifications

1.1 Reports Evolution

No.	Start Date	End Date	Description	Prepared by	Approved by
1	20-09-2023	04-10-2023	1st Deliverable Report	All members	G. Maldonado
2	04-10-2023	01-11-2023	2nd Deliverable Report	All members	G. Maldonado

Table 1: *Project Milestones*

1.2 Scope

This report aims to compile the results of the technological research carried out in the different areas necessary for the development of this project, with special attention to its main objective, which is the detection of drowsiness in driving. The comparison and analysis of the state of the art will help to determine the most effective method and the reasons for choosing it. In addition, this paper aims to justify the various software and tools applied in areas such as programming and web page design.

1.3 Background

To identify drowsiness, it is essential to evaluate various signs associated with it. Given their diverse nature, multiple detection methods are available. These approaches for recognizing **drowsiness-related indicators** in a vehicle driver can be grouped into three main categories:

- Based on **physiological measurements**: using electrocardiogram (ECG or EKG), electroencephalogram (EEG), electromyogram (EMG).
- Based on measurements of **the vehicle**: detecting abnormal behavior on it.
- Based on **computer vision**: monitoring of physical symptoms on the driver such as head movement, eyes activity and facial expressions.

Each of these methods offers some advantages or disadvantages over the others. For example, physiological measurements allow early detection of drowsiness, but the equipment used can be quite intrusive for the user (driver). Whereas vehicle behavior depends on more than one factor, such as driver experience, weather conditions, vehicle manufacturer and model. Similarly, computer vision depends on image quality, which is affected by the camera used and lighting conditions.

1.4 State of the Art

There are numerous symptoms that can be assessed to detect drowsiness in a driver. In computer vision, the **physical symptoms** are observable and can be processed through imaging. Based on extensive research in several articles, we have condensed these symptoms into the following list:

In the eyes area:

- Blinking frequency
- Maximum duration of eye closure
- Percentage of eyelid closure
- Aspect ratio of eyes
- Eyelid curvature

In the mouth and head:

- Frequency of yawning
- Aspect ratio of mouth curvature
- Mouth opening time
- Frequency of head movement
- Analysis of head movement

Regarding the eyes, a standard blink typically lasts 100-400 milliseconds. However, when drowsiness sets in, the duration of eye closure tends to increase, making a longer blink duration a potential sign of drowsiness [19]. As for the mouth, yawning, a well-recognized symptom of drowsiness, involves a quick action where the mouth opens and closes, lasting approximately 4 to 6 seconds [1].

1.4.1 EAR Eye Aspect Ratio

As previously mentioned, most of the features used to detect fatigue through imaging are extracted from eye regions. Many researchers propose the Eye Aspect Ratio (EAR), which is a metric that allows to **detect blink frequency** using facial features. With this metric, the degree of eye opening can be determined. This parameter is generally used to train models. Another project concludes [18] that using EAR brings many advantages over using a traditional image detection method. This ratio uses 6 coordinates in the eye, this ratio is generally kept constant, but drops to zero if the eye is completely closed as shown in Fig. 1.

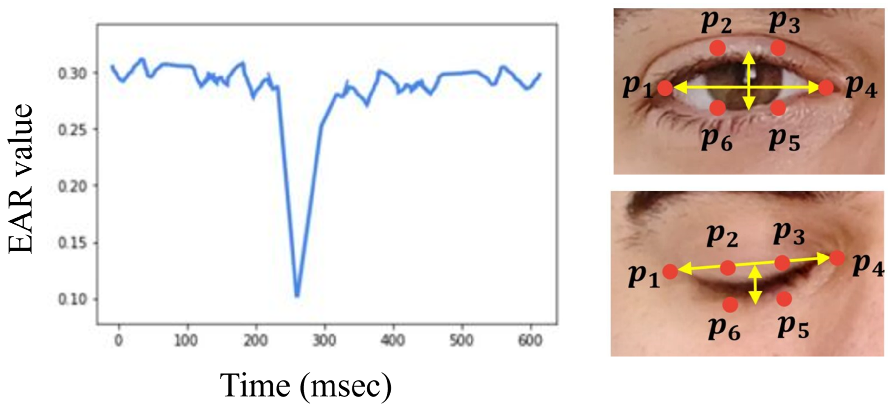

Figure 1: *EAR change over time. Source: [1].*

The equation to calculate the EAR is shown below, as seen on it the distances between landmarks is used.

$$EAR = \frac{||\mathbf{p}_2 - \mathbf{p}_6|| + ||\mathbf{p}_3 - \mathbf{p}_5||}{2\,||\mathbf{p}_1 - \mathbf{p}_4||} \tag{1}$$

1.4.2 MAR Mouth Aspect Ratio

Another commonly used parameter is to evaluate the behavior of the mouth to detect yawning while driving. Initially, the area of the mouth is categorized from the images, and then the degree of mouth opening, known as the Mouth Aspect Ratio (MAR), is used to identify yawning (see Fig. 2). In other studies [1], when this feature is combined with others, it has achieved a notable 97% accuracy.

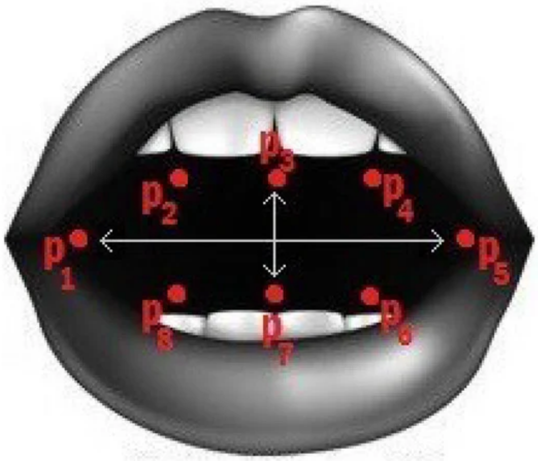

Figure 2: *The coordinates used to calculate the MAR. Source: [4].*

The MAR calculates the **degree of mouth opening**, similar to how the EAR utilizes eye coordinates to establish whether the eyes are open or closed. The MAR ratio is computed as follows:

$$MAR = \frac{||p_2 - p_8|| + ||p_3 - p_7|| + ||p_4 - p_6||}{2||p_1 - p_5||} \tag{2}$$

1.4.3 Convolutional Neural Networks

To obtain features such as facial landmarks or segment image areas, the most popular techniques are based on machine learning algorithms. Among them, neural networks, especially convolutional neural networks (CNNs), are widely used for image processing [24].

As an example of the output of a CNN, in Fig. 3, we can observe a driver with a framed indication of the face's position and some relevant red landmarks on the face.

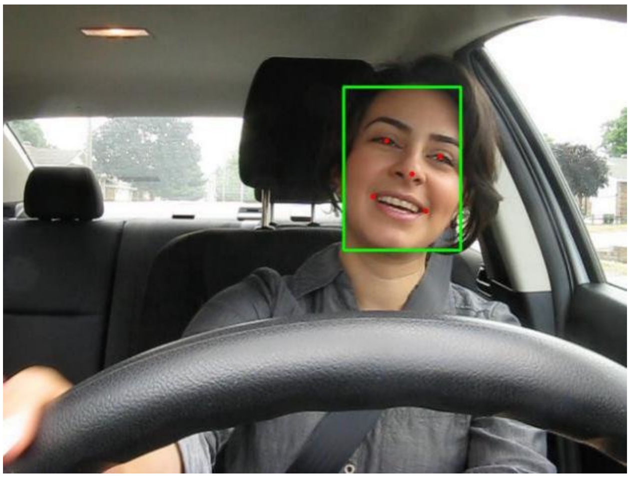

Figure 3: *Facial detection. Source: [9].*

1.4.4 Summary Table

A comprehensive analysis of various research studies is conducted to examine the methods employed for symptom analysis. Furthermore, the effectiveness of these methods is compared in Tab. 2.

Authors	**Method**	**Landmarks**	**Performance**	**Complexity**
Horng et al. [8]	• Determine human skin color • Locate face • Edges to locate eye • Determine whether the eye is open or closed.	Drowsiness index with five consecutive frames of closed eyes.	75-85%	Low
Panicker et al. [17]	• Color through YCbCr • Projection functions • Complexity function	• Eye closure frequency • PERCLOS	70-80%	Medium
Ching-Hua Weng [22]	Neural networks	Deep Belief Network (HTDBN)	> 85%	High
Albadawi et al. [1], H. Garg [6], A. Martínez [13]	Fusion of different indicators	• MAR • EAR • Tait-Bryan (Navigational-angle)	> 85%	Medium

Table 2: *Comparison of Methods for Drowsiness Detection*

1.5 Resources and tools

Here, we provide a brief summary of the available datasets, the chosen programming language, the best development environments for this project, and we also discuss notable programming libraries.

1.5.1 Available Datasets

The datasets to be used in this project are a primordial part. Consequently, a research was conducted on the available datasets online and their characteristics, which would be useful for different stages of the development of the project. On the first hand, it was found the MRL dataset [5], with a collection of more than 80k images (an example of these can be seen in Fig. 4) which are labeled on gender, glasses, eye state, reflection and light conditions. Also, it was found a blog [26] with a collection of best datasets available. These datasets address different goals, and thus their collection include different labels and markers. Among these datasets we have LPW, GazeCapture, NVGaze, MagicEyes and OpenEDS.

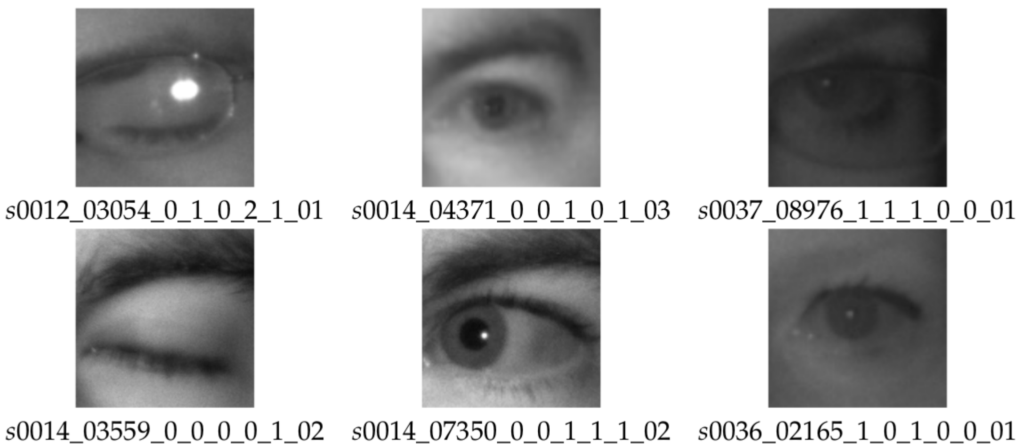

Figure 4: *Examples of image annotations of the proposed MRL dataset [5].*

In addition, the importance of landmarks in the images was outlined and focusing on that approach for the datasets, another blog [3] contains a collection of 3 datasets with landmarks available which are 300W, 300-VW, and AFLW. Another collection of public datasets with landmarks [25], contain the previous datasets as well as other 5 datasets, among them the HELEN dataset from Imperial college London and WFLW from Tsinghua National Laboratory. The benefit of this last collection is that it allows an easy implementation in a training model with python.

1.5.2 Programming Language

Python has been selected as the programming language due to the familiarity of most team members with this language. Moreover, it enjoys global popularity and offers a wealth of resources and documentation, particularly in the field of computer vision.

1.5.3 Programming Environments

As a programming environment we will use *Jupyter Notebooks* through the *Google Colab* tool, so we can all work on the same document. In order to work in real time, we will use *Visual Studio Code* with the *LiveShare* extension. The main logos for these programming environments are provided in FIG. 5.

Figure 5: *From left to right: Google Colab[2], Jupyter Note Books [10], Visual Studio Code [14] and Live Share [15]. These environments will allow us to develop the code needed for this project.*

1.5.4 Programming Libraries

- **OpenCV:** Library used for image processing in Python, used for facial recognition enabling filtering, edge detection, feature recognition, object tracking, etc. [7].
- **TensorFlow:** This library will allow us to build and train neural networks to detect patterns and reasoning used by humans. [11].

The main logos of these libraries used in the programming environment are found in FIG. 6.

Figure 6: *From left to right: OpenCV [16], Keras [12] and TensorFlow [23]. These libraries will allow us to develop the code needed for this project.*

1.6 Methodology

Once the study of the state of the art has been carried out, we proceed to specify the itinerary to be followed. The following proposed methodology presents, on the one hand, the conclusions regarding the tools to be implemented, and on the other hand, a planning in which the solution of the problem is approached in sequential stages.

1.6.1 Selected Tools

Based on previous projects it has been decided:

- Employ **Python** as a programming language.
- Focusing our interest on the **detection and segmentation of eyes, mouth and head**. Measuring the percentage of blinking, yawning and the degree of inclination and movement respectively.
- Employing neural networks, specifically **CNNs**. We believe it is possible to reach a reliability of 85% in our systems (as commented in Tab. 2).
- Train the networks and perform system validation through **Google Colab**, as it **allows the use of acceleration hardware (GPUs)** at no cost for the user.
- Perform a step-by-step approach to the problem. As explained below. Where the selected dataset will be the MRL [5] for infrared images of the eyes. The other for stage 2 will be selected between those in [26].

1.6.2 Planning in Stages

A first stage will solve the problem by means of a simple but functional implementation. In successive stages, the aim is to improve and add complexity to the system by allowing, for example, the analysis of videos instead of just images. Alternatively, it could include not only eye detection but also mouth detection by means of an extra neural network. In Fig. 7 you can see the steps of the proposed implementation.

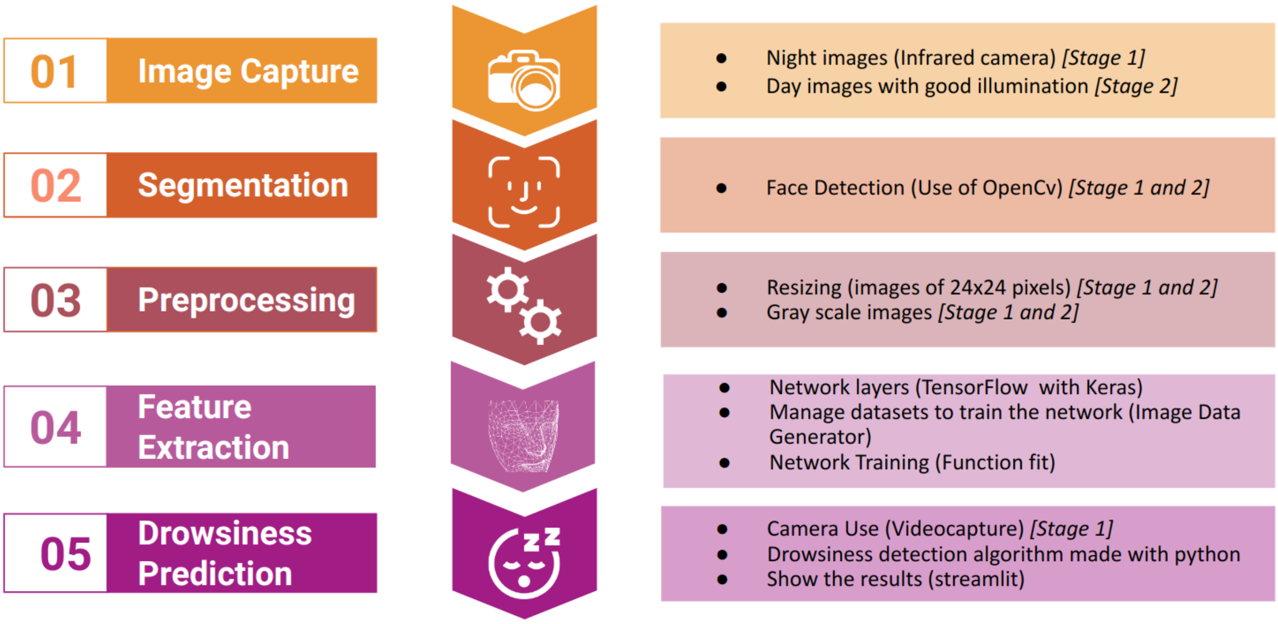

Figure 7: *Methodology proposal for the drowsiness detection system.*

Firstly, the images are captured (phase 1 would correspond to taking color images or infrared camera images and phase 2 would consist of being able to analyze videos in real time). Secondly, using the *OpenCV* library, the segmentation of eyes and mouth is performed (this part is the same for both phases). Thirdly, the images are preprocessed by changing the size and converting them to grayscale (in both phases this process is identical). Fourthly, the images are analyzed by passing them to the trained networks (in phase 1 only images of the eyes will be analyzed and in phase 2 also of the mouth). Finally, a weighting of the estimated values is performed to conclude the level of drowsiness of the driver.

1.7 Website

A brief research was made for the purpose of determining the structure of the future website to be designed and the tools or platforms in which this could be carried out. Firstly, when it comes to structures, according to [20], there are four main types of websites: Hierarchical, Sequential, Matrix and Database (as shown in Fig. 8.a). It is chosen as the most appropriate one depending on the purpose of the website. In our case, **we found the hierarchical structure to be the most suitable**. In this structure, the user starts navigating from one main Homepage and into different subcategories. It is the most common structure used, hence the one in which the user might be more familiar with.

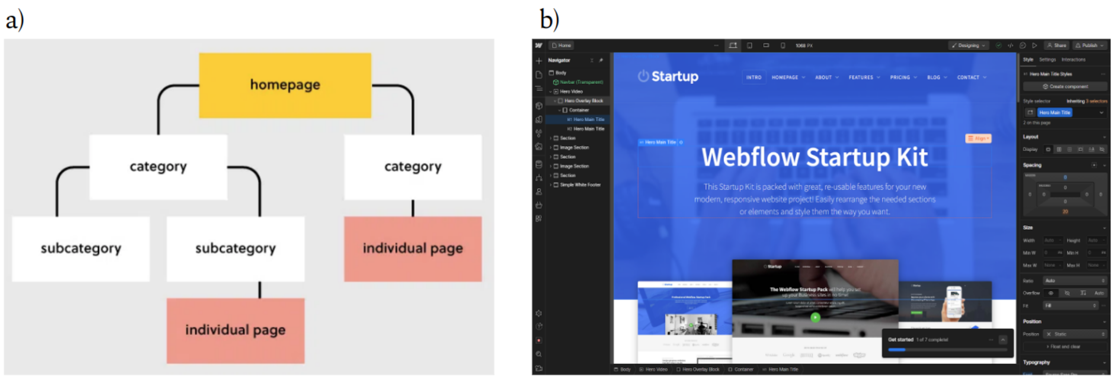

Figure 8: *a) Diagram of Hierarchical Website Structure [20] b) UI view of Webflow online tool [21]*

For the design of the website, among several platform options available it was decided to use *Webflow* [21], the same one that is visible in Fig. 8.b. Some of the advantages it offers are that it has a quite intuitive usage, easy to visualize as changes are made and allows previsualization on the look in different devices and different screen sizes. Additionally, it does not require coding, which helps on the live visualization of the changes made, and saves up time which can be destined to the main goal of the project.

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Annexes

The following pages contain the minutes numbers 3, 4, 5 and 6 of the group meetings related to this second delivery, which include the discussions and decisions made during these sessions.

INDUSTRIALES ETSII | UPM	PROJECT MEETING MINUTES			
	Editorial Date: ***04/10/2023***	Deliverable **2**	Minutes No. ***3***	Page No. ***1 of 2***

Project Information

Customer	UPM	Name	*Driver Drowsiness Detection*

ASSISTANTS		
Name	**Project Position**	**Registration No.**
Micaela Cabrera	Validation Manager	23023
Jorge Guijarro	Management Responsible	23075
Gustavo Maldonado	Documentation Manager	23102
Ivonne Quishpe	Technology Manager	23146

INFORMACIÓN MEETING

Date	04/10/2023	Start-End	18:30-19:30	Location	Online
Objectives	Planning the technological search and review of the previous delivery				

ITEMS TO BE DISCUSSED	
Review of the previous delivery	Firstly, the previous delivery was completed, correcting the small errors that remained.
Technological search planning	It was decided to divide the technological search into three teams: The first of them will seek information on the state of the art (SOA) of our problem (drowsiness and its detection). On the other hand, the second group will look for information about the chosen benchmark, specifically, from the different Data Sheets found. Finally, the last group will begin to search for information about the website on which the work will subsequently be developed.

TOPICS DISCUSSED
Those agreed in "Items to be discussed".

COMMITMENTS AND AGREEMENTS ADOPTED

No.	Description	Date of Application	Responsible	Expiration Date
0	Investigate the data sheets	01/10/2023	Jorge Guijarro José María	11/10/2023
1	Investigate SOA	01/10/2023	Micaela Cabrera Ivonne Quishpe	11/10/2023
2	Investigate Web Page	01/10/2023	Gustavo Maldonado	11/10/2023

NEXT MEETING AGENDA:	YES	X	NO		Date	11/10/2023

REMARKS
None relevant.

PREPARED BY: JORGE GUIJARRO TOLÓN. RESPONSIBLE FOR MANAGEMENT

INDUSTRIALES ETSII | UPM	**PROJECT MEETING MINUTES**			
	Editorial Date: ***11/10/2023***	Deliverable **2**	Minutes No. ***4***	Page No. ***1 of 2***

Project Information

Customer	UPM	**Name**	*Driver Drowsiness Detection*

ASSISTANTS		
Name	**Project Position**	**Registration No.**
Josep María Barberá	Programming Manager	17048
Micaela Cabrera	Validation Manager	23023
Jorge Guijarro	Management Responsible	23075
Gustavo Maldonado	Documentation Manager	23102
Ivonne Quishpe	Technology Manager	23146

INFORMACIÓN MEETING

Date	11/10/2023	**Start-End**	18:00-19:00	**Location**	Online
Objectives	Review each student's progress.				

ITEMS TO BE DISCUSSED	
Team 1 Research Review: State of the Art	Firstly, the main methods to detect fatigue were addressed: from Biological methods, through sensors in the vehicle and culminating with image recognition techniques. Next, this last section was delved into, indicating the main methods used, the most useful being the development of neural networks. There are different approaches: Detect only eyes or faces. Ideally, a hybrid method.
Team 2 Research Review: DataSheets	Various datasheets were found: Some only of eyes, others of faces, and even videos. It was decided to address, first of all, the case where working with photos, guaranteeing better results.
Team 3 Research Review: Web Page	Different environments were found to develop the website: WebFlow, Webz and Google (the latter had licensing problems). In addition, various structures were investigated to create said page (Hierachical websites and Matrix)

TOPICS DISCUSSED

Those agreed in "Items to be discussed".

COMMITMENTS AND AGREEMENTS ADOPTED

No.	Description	Date of Application	Responsible	Expiration Date
0	Searching for DataSheets and LandMarks	11/10/2023	Ivonne Quishpe Gustavo Maldonado	18/10/2023
1	Find and Implement the neural network with Python	11/10/2023	Josep María Barberá Jorge Guijarro	18/10/2023
3	SOA: Effectiveness/Justification-Importance of the problem. Features table	11/10/2023	Micaela Cabrera	18/10/2023

NEXT MEETING AGENDA:	YES	X	NO		Date	18/10/2023

REMARKS

None relevant.

PREPARED BY: JORGE GUIJARRO TOLÓN. RESPONSIBLE FOR MANAGEMENT

INDUSTRIALES ETSII | UPM	PROJECT MEETING MINUTES			
	Editorial Date: ***18/10/2023***	Deliverable **2**	Minutes No. ***5***	Page No. ***1 of 2***

Project Information			
Customer	UPM	**Name**	*Driver Drowsiness Detection*

ASSISTANTS		
Name	**Project Position**	**Registration No.**
Josep María Barberá	Programming Manager	17048
Micaela Cabrera	Validation Manager	23023
Jorge Guijarro	Management Responsible	23075
Gustavo Maldonado	Documentation Manager	23102
Ivonne Quishpe	Technology Manager	23146

INFORMACIÓN MEETING					
Date	18/10/2023	**Start-End**	18:30-19:30	**Location**	Online
Objectives	Review each student's progress.				

ITEMS TO BE DISCUSSED	
Team 1 Research Review: DataSheets and LandMarks	A first way did not work (Data Shets with LandMarks) The second was a DataSheet with more images and labels. Bad results when using a protocol (TCP) that requires a lot of memory (2TB). Finally, a notebook with a collection of DataSets and LandMarks was found, obtaining optimal results. The model creates the LandMarks in the DataSheet. This model works like a Neural Network. You would need 2: One for the eyes and one for the yawn.
Team 2 Research Review: Neural network	It was proposed to use Google Colab as an execution environment by allowing the use of a GPU with 12 hours of processing and various programming languages.
Team 3 Research Review: State of Art	A table was made comparing different implemented methods. The most optimal thing is to use several methods at the same time. The Viola-Jones Algorithm compares head tilting, yawning, and blinking. Furthermore, it was proven that the better the datasheet and mesh, the better results were obtained.

TOPICS DISCUSSED
Those agreed in "Items to be discussed".

COMMITMENTS AND AGREEMENTS ADOPTED

No.	Description	Date of Application	Responsible	Expiration Date
0	Investigate the documentation found in search of programming with neural networks.	18/10/2023	Jorge Guijarro	25/10/2023
1	Delivery writing	18/10/2023	Micaela Cabrera Gustavo Maldonado	25/10/2023
2	Testing found code	18/10/2023	Josep María Barberá Ivonne Quishpe	25/10/2023

NEXT MEETING AGENDA:	YES	X	NO		Date	25/10/2023

REMARKS
None relevant.

PREPARED BY: JORGE GUIJARRO TOLÓN. RESPONSIBLE FOR MANAGEMENT

INDUSTRIALES ETSII | UPM	**PROJECT MEETING MINUTES**			
	Editorial Date: ***25/10/2023***	Deliverable **2**	Minutes No. ***6***	Page No. ***1 of 2***

Project Information

Customer	UPM	**Name**	*Driver Drowsiness Detection*

ASSISTANTS		
Name	**Project Position**	**Registration No.**
Josep María Barberá	Programming Manager	17048
Micaela Cabrera	Validation Manager	23023
Jorge Guijarro	Management Responsible	23075
Gustavo Maldonado	Documentation Manager	23102
Ivonne Quishpe	Technology Manager	23146

INFORMACIÓN MEETING

Date	25/10/2023	**Start-End**	18:30-19:30	**Location**	Online
Objectives	Review each student's progress.				

ITEMS TO BE DISCUSSED	
Team 1 Investigate the documentation	The operation of convolutional neural networks was investigated, as well as the state of the art and the evaluation characteristics of some documents presented.
Team 2 Delivey Writing	The first parts of the report was written correctly.
Team 3 Testing found code	Some small tests were performed, resulting in better performance in Python than in other candidate programming environments.

TOPICS DISCUSSED
Those agreed in "Items to be discussed".

COMMITMENTS AND AGREEMENTS ADOPTED

No.	Description	Date of Application	Responsible	Expiration Date
0	Writing 1: Outline State of Art, Python Libraries, DataSheets, Scope	25/10/2023	Gustavo Maldonado Ivonne Quishpe	01/11/2023
1	Writing 2: “Definitive Choice”	25/10/2023	Micaela Cabrera Josep María Barberá	01/11/2023
2	Check working code in Python	25/10/2023	Micaela Cabrera	01/11/2023
3	Check the Datashet and decide the final one: See how it works, open images...	25/10/2023	Jorge Guijarro	01/11/2023

NEXT MEETING AGENDA:	**YES**	**X**	**NO**		**Date**	01/11/2023

REMARKS
None relevant.

PREPARED BY: JORGE GUIJARRO TOLÓN. RESPONSIBLE FOR MANAGEMENT