TED UNIVERSITY

CMPE 491

High-Level Design Report

Project Name: Drive Safe-Off

Team Members

Gökçe BEKAR

Rabia Esra ŞENDUR

Rumeysa OMAY

Oğuzhan Uğur SARISAKALOĞLU

Supervisor

Venera ADANOVA

Jury Members

Aslı GENÇTAV

Orkunt SABUNCU

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1. Introduction

The drive safe-off project is a system that detects drowsiness while driving and gives a warning to the driver. The main purpose of this system is that drivers have a great impact on accidents. A study in 2014 by the AAA Traffic Safety Foundation reported that 37 percent of drivers slept behind the wheel at some point in their lives. An estimated 21 percent of fatal accidents, 13 percent of accidents with serious injuries, and 6 percent of all accidents involve a drowsy driver.

This system, on the other hand, tracks facial movements such as eye closure and yawning while the driver watches and watches. If the result obtained indicates that the driver is drowsy, the system warns the driver with sound, but if there is no improvement after the warning, it sends a notification to the person who needs to be reached.

In this report, the system that has been created so far and will be formed in the future, Proposed software architecture with subtitles and Subsystem services will examined.

1.1 Purpose of the system

It is known that driver errors due to drowsiness are a major contributor to many motor vehicle accidents. For example, various sources indicate that driver fatigue is the probable cause of approximately 30 percent of accidents (Folkard, 1997; Horne and Reyner, 1995; Kecklund and Åkerstedt, 1993; Lenne, Triggs and Redman, 1997; Lynznicki, Doege, Davis, and Williams, 1998; National Transportation Safety Board, 1990). Fatigue is known to reduce driver attention and reaction time. For this reason, tired drivers pay less attention to the driving environment and are more likely to make mistakes, which reduces their probability of detecting potential conflict situations and responding to conflict situations. For example, Dinges (1995) reported that the reaction time of tired drivers decreased by 5 percent to 25 percent. In recent years, there has been little progress in reducing road traffic injuries. Among the various reasons, the most important is the driver's fatigue and sleepiness. This reduces the driver's decision-making ability to control the vehicle. Symptoms of being sleepy or drowsy include difficulty focusing, frequent blinking, daytime dreaming, missing traffic signs, repeated yawning, etc. Takes place. According to statistics, it was stated that the drowsiness of the driver killed 1,500 people and injured 71,000 in traffic accidents that occur in the USA every year. About 20% of serious road accidents and 30% of fatal accidents involve driver errors, according to the Australian survey.

Given the impact on the threats of driver drowsiness, it is necessary to develop a system that provides a real-time warning to the driver and can monitor and measure driver drowsiness. Driver drowsiness can be detected by considering biological parameters such as electroencephalogram (EEG), electrocardiogram (ECG), but this method requires the electrodes to be connected to the driver's body and is not a preferred method because it will disturb the driver. Another method that can be used to detect drowsiness is to look at vehicle-based behaviors such as the position of the car on the roads, the movement of the steering wheel, as well as behaviors such as yawning in the blink of an eye, ie driver-based behavior. However, since vehicle-based methods depend on driving skills, it is difficult to establish standardized rules over the driver and the vehicle.

Therefore, this study will examine the driver's face behavior. These include eye closure time, yawning, and frequently repeated eye-closing behaviors.

1.2 Design goals

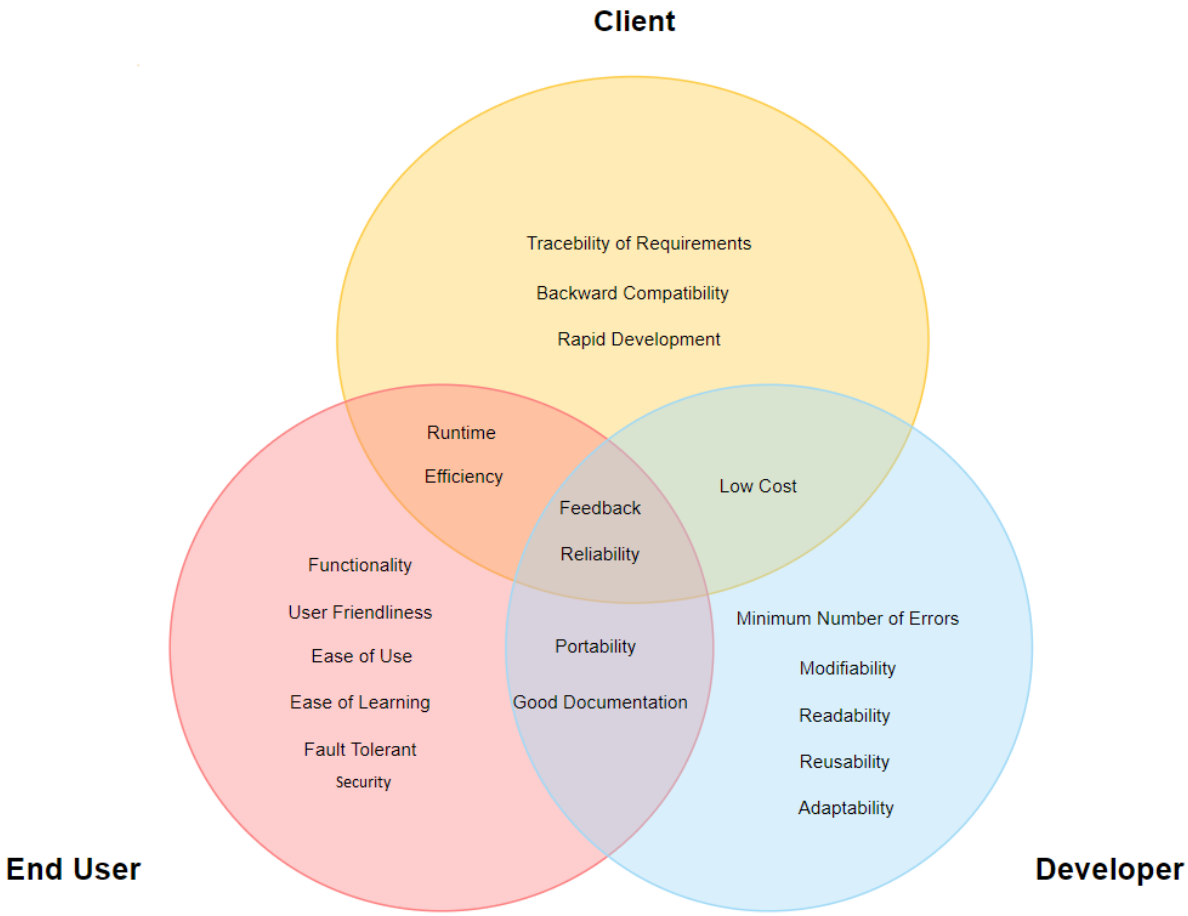

Figure 1: The illustration of design goals.

As shown in Figure 1 above, we divided our project into three main actors which are client, end-user, and developer. In order to develop with a professional approach, we separated the needs of developers, clients, and end-users in our project and analyzed them in more detail. By adopting the professional approach in business life, we separated the expectations and requirements of the developer, the client, and the end-user. These requirements and their explanations are as follows,

Modifiability: The system will be easy to modify as long as the developer(s) have the knowledge of Python, OpenCV, Matlab, etc.

Portability: In terms of portability, our system will be able to work on platforms such as computers and Raspberry Pi where the power source is available.

Readability: The readability for this system will be ensured by the comments we write in our codes. In this way, the developer will be able to easily understand the code when any change is desired.

Low Cost: No equipment other than Raspberry Pi and camera kit will be used in the development of this system. This will keep the cost low.

Adaptability: The system will be able to adapt to changes easily.

Performance / Response Time: A device that is unable to detect drowsiness and warn the driver inefficiently can have severe consequences. The response time of the device should be fast and the alert should be effective enough to make the driver sober up.

Reliability: The system should identify drowsiness correctly so that it can serve its function as a driver safety promotion device. The system defect rate shall be less than 1 failure per 1000 hours of operation.

Maintainability: The system shall not be shut down for maintenance more than once in a 24-hour period.

Usability (Ease of Use, Ease of Learning and User Friendliness): The use of the device should be as simple as possible. People who are not trained to use the system will be able to use the product.

Security: The driver's personal information shall not be accessed or reached by anyone.

Accessibility: The system shall be accessible to a wide range of driver as well as the prevalence of driver's license.

Efficiency: The system restart cycle must execute completely in less than 60 seconds. The system should deliver a notification in 1 second or less.

Good Documentation: Readme.txt will be provided so that any user can easily operate and use the system.

Feedback: An alarm will be given to warn the driver.

Rapid Development: Having a lot of research on this issue before will speed up the implementation much more. In this way, it plays an important role in developing a more efficient system.

1.3 Definitions, acronyms, and abbreviations

Session: Time interval between driving start and end.

Supervisor: The person is the administrative authority of the environment of the system.

User: The person driving the car on the scene in a session

GUI: Graphical User Interface

EAR: Ear aspect ratio

MAR: Mouth aspect ratio

1.4 Overview

In order for the driver to detect drowsiness, many stages must occur. After getting on the vehicle, the driver has to turn on the system and go through many stages such as processing the image taken in real-time. These stages are illustrated below.

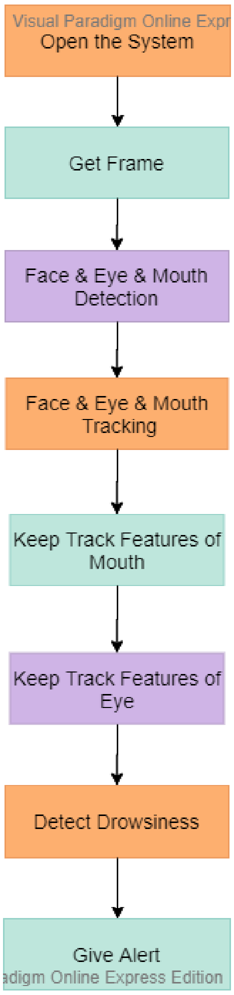

Figure 2: The stages which is needed for creating system.

As shown in Figure 2 above, the system starts with the driver turning on the system after getting in the car. First of all, the driver's face is detected by the system. Then, the eye is detected to determine the rate of drowsiness. After detecting the driver's face and eye, the tracking process starts as the driver's movement will not be constant. In order to analyze the state of the eye better, the features of the eye are used during tracking. As a result, the eye aspect ratio is calculated and the aperture ratio of the driver's eye is continuously monitored. When the eyelids are closed for a while, a warning sound is given to the driver and the driver becomes aware of her/his drowsiness.

Based on the stages in Figure 2, current and proposed systems have been created. It will be explained in more detail later in the report.

2. Current software architecture (if any)

Current software architecture enables the system to deliver a simple network that notifies actors during a driving session. For this, the designed architecture in the figure above is delivered in the project analysis report. This architecture faced us with uncertainties. For example, the subsystem of the storage subsystem. The system that implements a connection between the driver machine and server machine needs to be driven by data. Also, the steps of drowsiness detection that is computed in the driver machine need the implementation of a tracking subsystem.

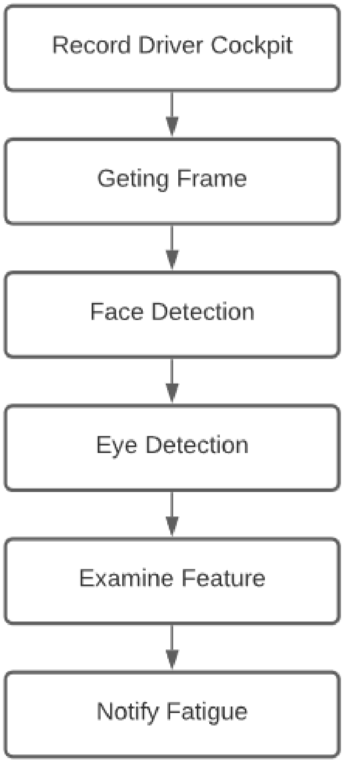

Figure 3: The illustration of current system.

The proposal system architecture will solve problems that we have faced in the current system. These improvements consist of various parts. For example, the computing eye ratio does not give accuracy. Because of depending on one constant, the improvement that adds mouth aspect ratio subsystem. These ratio computing improvements change the system at the examining and eye detection steps to Eye Aspect Ratio and Mouth Aspect Ration Subsystems. Also proposal system architecture implements a solution for mouth detection. To sum up, the reliability is improved by passing multiple parameters.

At the state of development, the current system architecture can be improved as abstracted in the following figure.

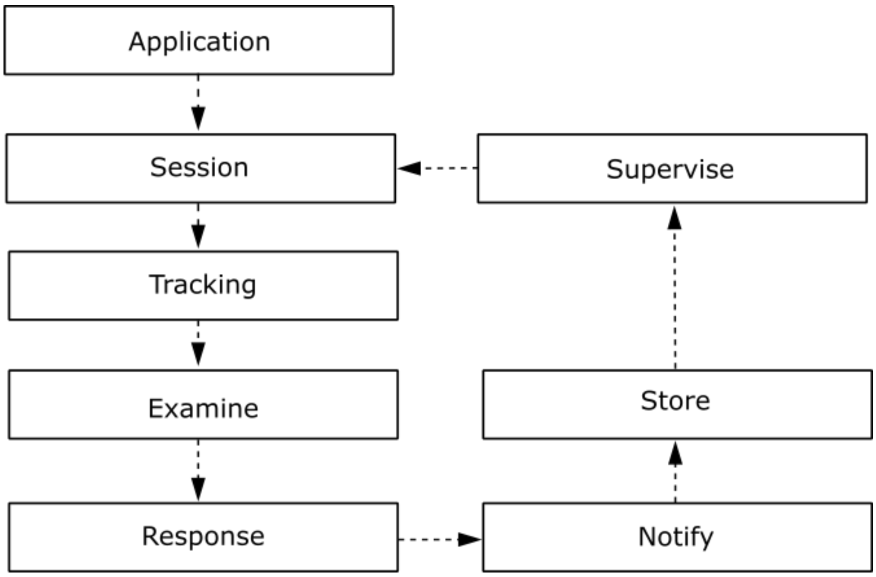

Figure 4: Improved current system architecture with logical components

A component that starts the process circle is the Application component. At this step, a driver can login into to system with a stable version of the software at the driver's hardware. For this, a service that implements an auth policy is to administrate by the supervisor the activity from the server machine.

The new session starts with a successful authentication process in a stable version of the software. At the Session component, the drivers' features enable the software to investigate drowsiness in the Tracking component. This logical component follows the eye and mouth states of the driver in a passed frame. Investigation of eye and mouth states can be used for computing their aspect ratios. For this, the Examine component consists of the algorithms that are used to calculate their aspect ratios and use them for calculating the drowsiness level of the driver. At the state of the Response component response this drowsiness to the system.

As the purpose of the system that notifies the drowsiness to the actors, the Notify component communicate with actors that are driver, supervisor, and 3rd actors during the situation that emergency is needed.

For the maintenance of the product during its life cycle, the system consumes the stored data from previous sessions. Consequently, the system improves by updates that are passed to supervise components. The Supervise logical component introduces users to a stable version of the software and authentication service to the system.

3. Proposed software architecture

3.1 Overview

In this part, our system of system decomposition, hardware-software mapping, persistent data management, access control and security, global software control, and boundary conditions will be introduced. In the Subsystem decomposition part, it is explained how many subsystems our system consists of and what they are. Subsystems are shown on the figure for better understanding and their relationships with each other are indicated. In addition, in the hardware and software mapping part, how many devices our system consists of, what they are, and which components they contain are shown with figures. UserMachine and ServerMachine have been introduced in detail separately. At the same time, the relationships of the components with each other are shown through the figures. Furthermore, in the persistent data management section, which is another important issue, we gave information about which data we will store and how to store it. In the access control and security section, it was explained in detail which types of users have the right to access the system and what kind of access authorization they have. Also, the interface to be logged into the system was designed with HTML and added to the report. Moreover, in the global software control section, how the system started to work, and the order in which the operations took place was introduced.

3.2 Subsystem decomposition

First of all, our drowsiness detection system has a subsystem called the eye aspect ratio & mouth aspect ratio. This subsystem consists of six subsystems. These are Eye Aspect Ratio (EAR, Mouth Aspect Ratio, tracking, login, notification, and storage. In addition, high cohesion means that the classes in the subsystem perform similar tasks and are related to each other (via associations). Also, coupling measures dependencies between subsystems. Thus, if there is high coupling, changes to one subsystem will have a high impact on the other subsystem. Therefore, subsystems should have as maximum cohesion and minimum coupling as possible. Consequently, we aimed to use as few subsystems as possible in our system, since a large number of subsystems will increase complexity.

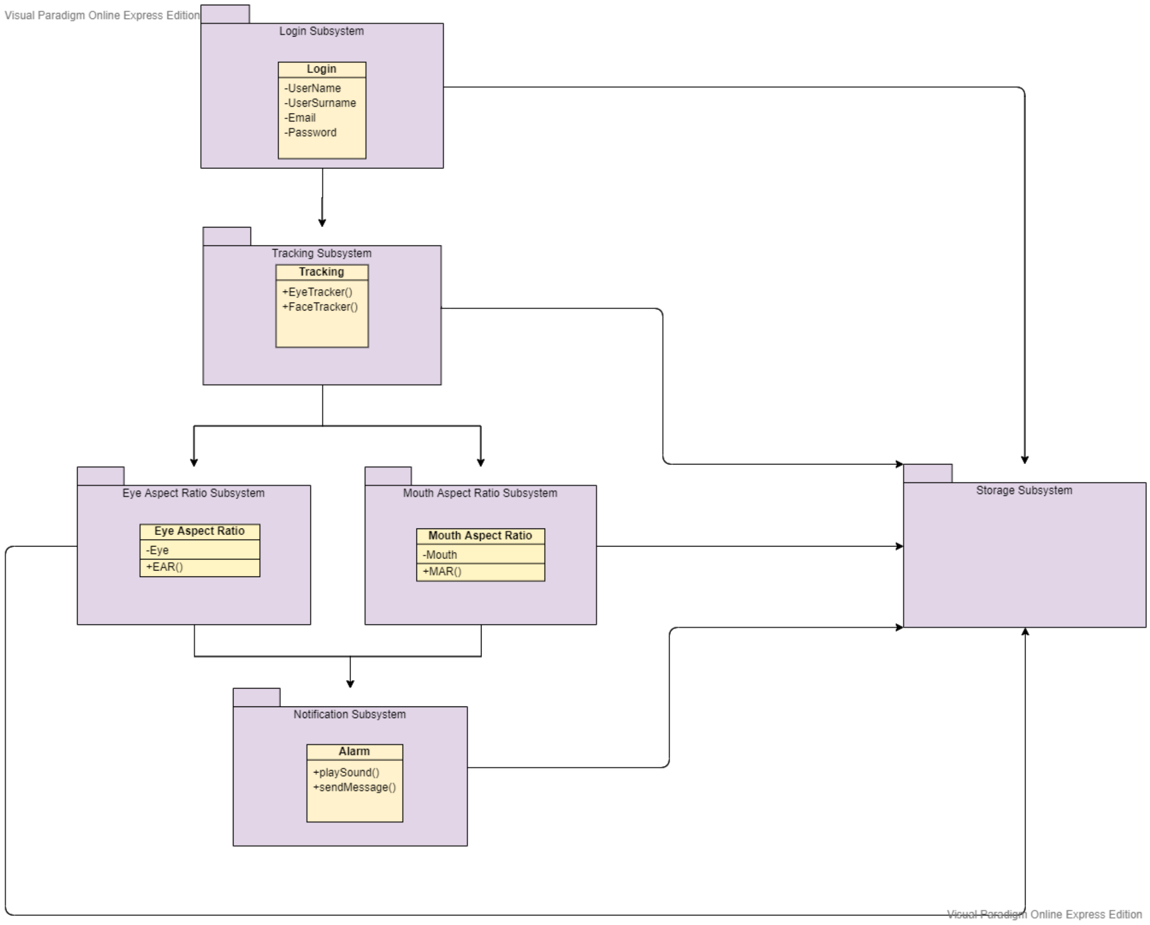

Figure 5: The subsystem decomposition of Drive Safe-off.

Login Subsystem: Supervisor and user must log in to the system to use the system. The person who will use the system can log into the system with their name, surname, email and password. Then, the tracking process begins when the driver gets in front of the camera and open the system.

Tracking Subsystem: Object Detection using Haar feature-based cascade classifiers is an effective object detection method proposed by Paul Viola and Michael Jones. It is a machine learning-based approach where a cascade function is trained from a lot of positive and negative images. It is then used to detect objects in other images. After detection, the face and eye tracking process was performed with the EyeTracker function in Python's cv2 library.

Eye Aspect Ratio Subsystem: The features of the eye are calculated using images of the eye at different apertures. Eye Aspect Ratio (EAR) will be reduced if the driver's eye is closed for a long time. Therefore, a warning will be sent by the system. The following figures 5 and 6 show how the Eye Aspect Ratio (EAR) is implemented and the formula used for this situation.

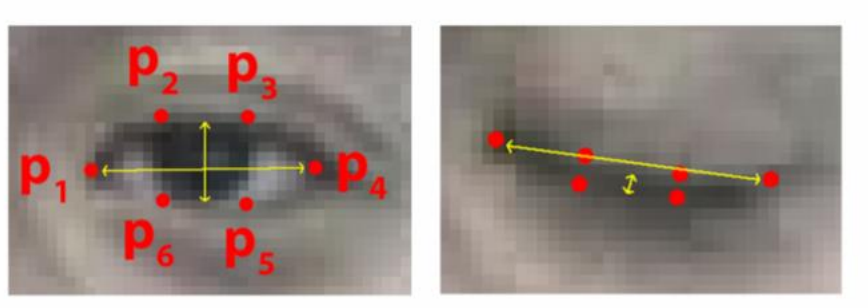

Figure 6: The points used in calculating the EAR are (left), the position of the points with the eye closed (right).

$$\text{EAR} = \frac{\|p_2 - p_6\| + \|p_3 - p_5\|}{2\|p_1 - p_4\|}$$

Figure 7: Formula of Eye Aspect Ratio (EAR).

Mouth Aspect Ratio Subsystem: One of the most important factors used in determining the driver's drowsiness is yawning. In order to determine the duration and frequency of these yawnings, the aspect ratio method applied in the eye is used. Also, figure 8 shows how the coordinates used in the Mouth Aspect Ratio (MAR) are placed. Consequently, the opening of the mouth can be easily calculated with the Mouth Aspect Ratio (MAR) formula in the figure 9 below.

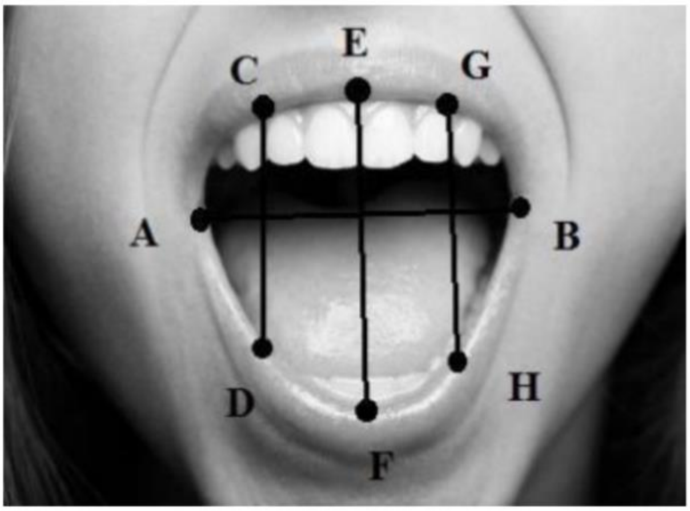

Figure 8: Coordinates of mouth.

$$MAR = \frac{|CD| + |EF| + |GH|}{3 * |AB|}$$

Figure 9: Formula of Mouth Aspect Ratio (MAR)

Storage Subsystem: When the system starts up, the data from all subsystems are stored. Therefore, all subsystems in the system are associated with the storage subsystem. First of all, when logging into the system, the session information of the user is recorded. Then, the tracking data initiated by the tracking subsystem are stored. Eye Aspect Ratio and Mouth Aspect Ratio subsystems working with tracking subsystem, create features for the eye and mouth and these features are stored for supervisor access.

3.3 Hardware/software mapping

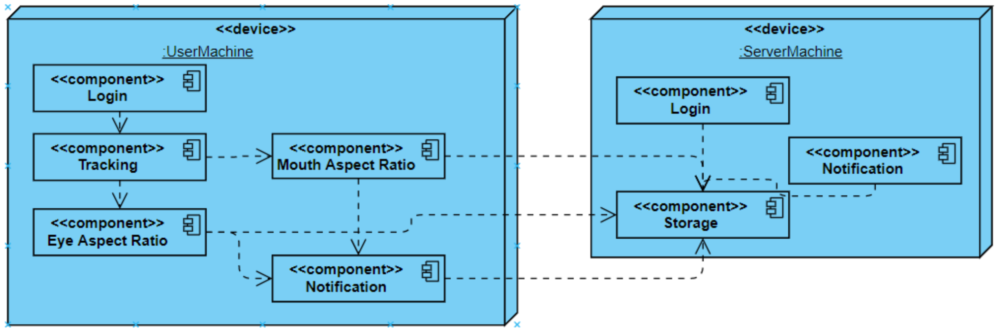

Figure 10: The hardware/software mapping of Drive Safe-Off.

As seen in Figure 10, the Drive Safe-off project is a distributed system because users, which are drivers and supervisor, can access the system in different locations and in front of different machines. However, only two types of nodes are distinguished: UserMachine to provide the user interface and perform the necessary operations after detecting the face in the tool, and ServerMachines to run application logic, storage, and more generally Drive Safe-off services.

UserMachine consists of Login, Tracking, Eye Aspect Ratio, Mouth Aspect Ratio, and Notification subsystems. As is known, UserMachine is hardware installed in the vehicle with raspberry pi. These are the software installed in subsystems such as Tracking, Eye Aspect Ratio, Mouth Aspect Ratio.

Users can login the systems with a web page, and supervisor and user subsystems are accessed via a Web server. After accessing the login page, it receives, processes and responds to requests from a Web browser. While tracking the face and eye in the vehicle, ear and mar values are calculated in UserMachine under Ear Aspect Ratio and Mouth Aspect Ratio subsystems.

The data calculated in Eye Aspect Ratio and Mouth Aspect Ratio subsystems or obtained in the Notification subsystem are transferred to the Storage subsystem in ServerMachine and kept permanently in the subsystem.

ServerMachine is a node created for administrative purposes to control and monitor the system when any problem is encountered in the system or to access any data file. It consists of Login, Notification and Storage subsystems. Login subsystem works in the same way as Login subsystem of User Machine. The only difference is that the ServerMachine has the priority to investigate and act in the system in case of emergency. It is another subsystem that is used to permanently save the data collected in the UserMachine in Storage and to access it when it is requested to be accessed. In the notification subsystem, the system that warns the driver about drowsiness while driving, sends the data to the storage subsystem every time it gives a warning.

3.4 Persistent data management

In order to be portable, we will transfer the codes written in Python with OpenCV and Matlab to the main board of Raspberry Pi. Therefore, we will use Raspberry Pi to store the codes. Consequently, the driver's frames can be instantly captured and processed with the Raspberry Pi Camera Module.

Besides, there will be two servers to store user information and video captures. User information, user session, face detection, and tracking data, will be stored on the UserMachine. Each user needs a space to store their username and password. It was decided to keep this in memory instead of the database. The data to be kept is not large, but it will be sufficient to keep it in memory. Supervisor information is already loaded to the user.

Another data to be collected was decided as follows. As is known, the system operates using the image of the person. Storing every frame used will be a huge burden for the system. Therefore, the data to be kept will be stored, the Eye Aspect Ratio (EAR), Mouth Aspect Ratio (MAR), values obtained after each frame, and if the user also exhibits a sleepy behavior, the data that will be used when sending a notification will be stored.

In addition, data such as Eye Aspect Ratio (EAR) and Mouth Aspect Ratio (MAR) data collected by the supervisor will be stored in the ServerMachine.

3.5 Access control and security

There are two different users in the system. These are supervisors and users. The supervisor is an administrator actor that interacts with the system directly with absolute authority. The user can access the data stored in the file. When the user is requested for checking systematic errors, it can perform functions such as monitoring the system.

Logging into a system, as shown in figure 12, requires a username, email, and password. Each user needs a space to store their username and password. It was decided to keep this in memory instead of the database. The data to be kept is not large, but it will be sufficient to keep it in memory. Supervisor information is already loaded to the user. The user will need to log in before the system can be used.

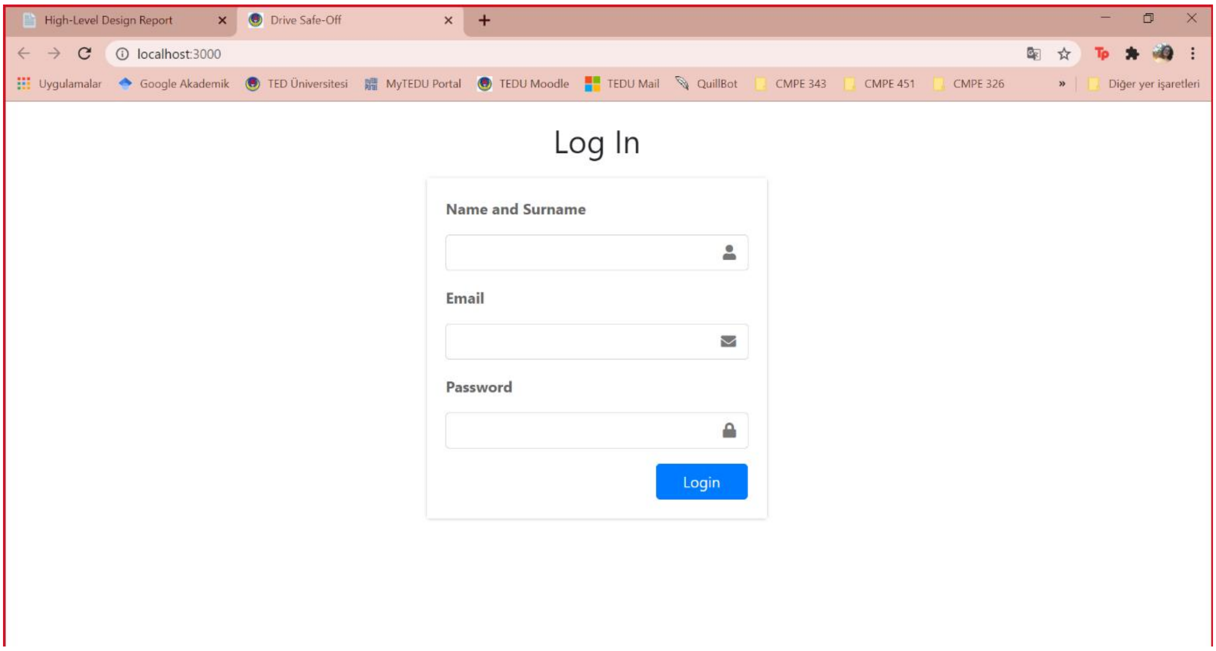

Figure 11: Interface of the login system

As Drive Safe-off is a multi-user system, user and supervisor are allowed to view different sets of objects and invoke different types of operations on them. To briefly document the access rights, an access control matrix was created for each actor, showing the allowed operations on entity objects.

Actor	Log in system of GUI	Viewing data file	Interrupting camera via GUI	Get Notificy
Supervisor	1	1	1	1
User	1	1	0	1
3rd Person	0	0	0	1

Table 1: Access matrix for main Drive Save-off.

As seen in Table 1, supervisor and user have a permission for log in the system using their user name and password. Both users have the right to review the recorded data after each ride after the system is turned off. Before the system is used, contact member is taken from the user. It is the third person (3rd person) to go to the notification in case of emergency. This third person has only the right to receive notifications.

3.6 Global software control

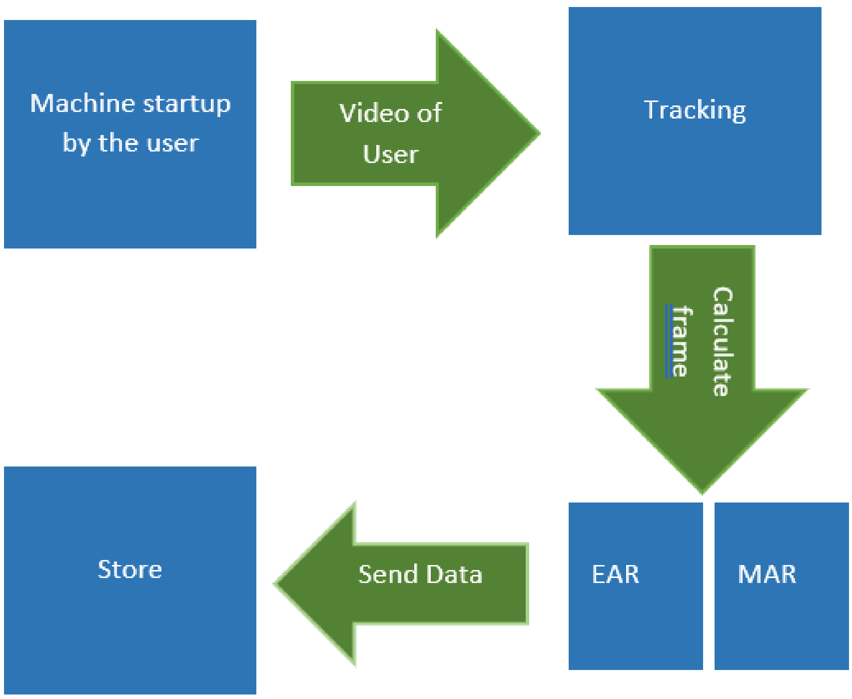

Figure 12: Illustration of global software control

Global software control describes how global software control is implemented. As can be seen in the figure 11, it is tried to explain how the system is started and how the subsystems are synchronized by visualizing. Our system starts with the driver logging into the system and running the program. As long as the system is running, it monitors the driver's actions and calculates the drowsiness. After the system is powered on, the driver's face, eye, and mouth are detected first, and then tracking starts. Detection, tracking, the feature of the eye, and mouth work synchronously. Therefore, detection, tracking, and feature of eye and mouth subsystems work concurrently. Eye aspect ratio and mouth aspect ratio are calculated thanks to the subsystems working concurrently. While the program is running, tracking, detecting, EAR, and MAR data are kept in storage. While detection and tracking data are stored on the UserMachine , the data collected by the supervisor (e.g. Eye Aspect ratio and Mouth Aspect Ratio) are stored on the ServerMachine. As a result, if drowsiness is detected, a warning will be sent to the driver simultaneously. In addition, more than one person can use the system at the same time as long as they have their own computer or Raspberry Pi.

3.7 Boundary conditions

Start-up and shutdown use cases

- *StartTheUserHardware*

For a driving experience with the system active, the hardware must be initialized. For this, an open button on hardware enables driver to access the gui that is used for authentication. After that, the session starts.

- *ShutdownTheHardware*

It expires when users turn off the system that was running on the vehicle. Termination in the vehicle can be done by both the user and the supervisor. Therefore, the supervisor can terminate the system with the GUI, while the user terminates with the button. The system records and saves the necessary information about that ride. When looking at the data such as how long the driver's eye is closed, how long he yawning, all data that can give an idea about the drowsiness of the driver during driving will be kept. If the system is not turned off after a certain period of time after the driver leaves the vehicle, the system should automatically turn itself off.

While the system determines the boundary conditions, it has been analyzed over several subjects. The boundary conditions of the system for a few cases are defined as follows.

- *Camera angle*

It will provide the boundary conditions of any system based on built-in cameras. The face of the driver to detect and track should be within the camera's field of view. If the driver's face is not within the camera's viewing angle, the face cannot be detected. If the face cannot be detected for a certain period of time, it will give an exception.

- *System operation*

The system needs to work 24/7 without any termination or perpetrator. From the user's point of view, when the driver gets into the vehicle, the system will start working when he presses the button in the hardware, and the system will shut down when the button is pressed before leaving the vehicle

- *GUI Initiation*

User or supervisor can log in via GUI. Therefore, the first step will be to log in to the system. When the user or supervisor enters the username and password correctly, the system will open a page according to that user's access authority.

- *Error Exceptions*

For GUI, users and supervisor, username and password mismatch is one of the errors that can give to login to GUI system. After five wrong attempts, the user will have to wait a certain amount of time to log back into the account, and every five times incorrect entry will be recorded by the system. For system in the vehicle, there should not be any malfunction for the system while driving. However, when the system encounters an unexpected situation or fails to function properly, it should be restartable.

- *Updating the System*

When an update is required, the sytem must be stable for updating time. For this, the interface will provides only updating statements.

4. Subsystem services

Subsystems are identified from the scenarios of the system's functional requirements of the system. For this, system can be divided to self-contained components that can be managed by individually and refining the subsystem decompositions identified subsystem services.

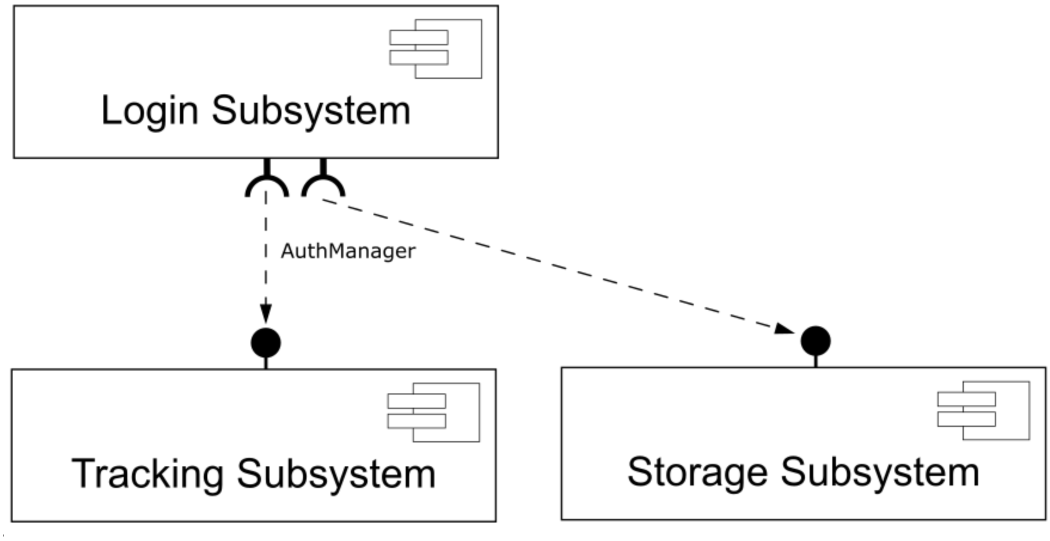

Figure 13: Representation of Authorization & Authentication Service

Authorization & Authentication

An user experience oriented system is starts with and authentication application and maintains on authorization. The authentication aims to starts, process and ends the session with a unique driver as a user of system or enables supervisor to investigate the data on driver machine. As seen in the figure above, AuthManager implements the service of authorization and authentication.

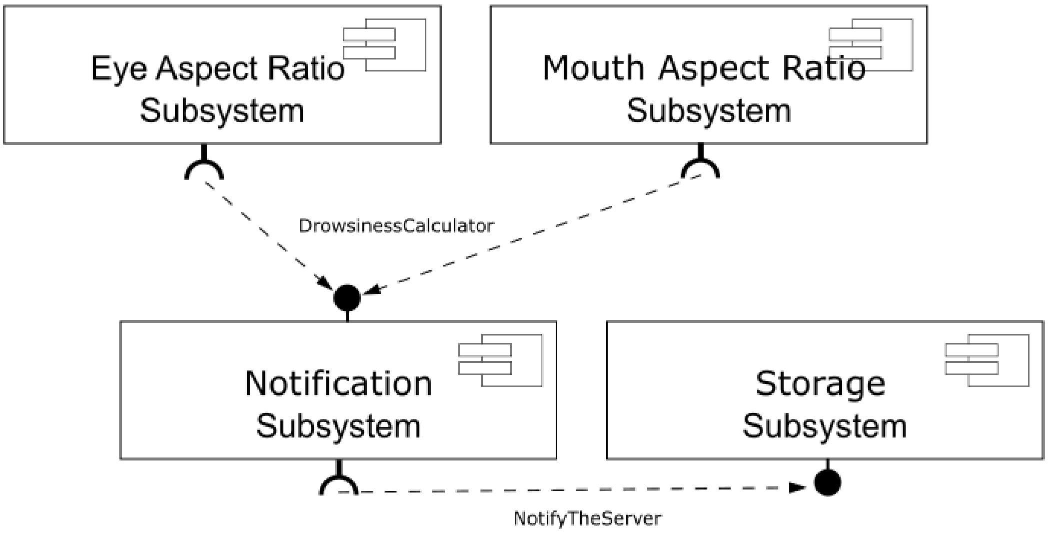

Figure 14: Representation of Notification service

Notification in extraordinary situations on driving session.

The fundamental purpose of the system is preventing the losses of the drowsiness in the traffic. For this, when the notification subsytem is warned by the ratio subsystems, the alert will be stored into to the server machine by the NotifyTheServer.

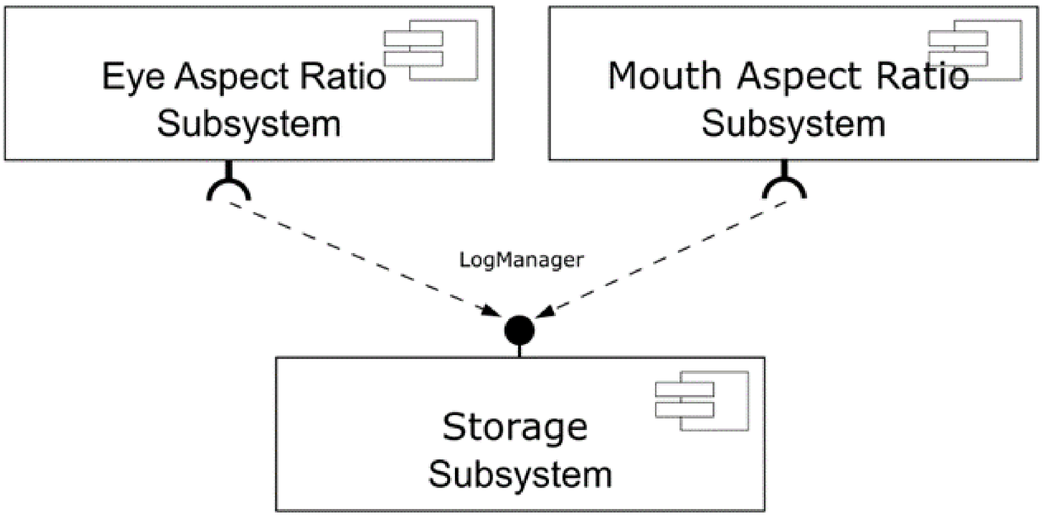

Figure 15: Representation of Log Service

Register the Ratio Log at the Session To Storage

Logs of ratio computing entire driving session are stored in the storage subsystem that is located at the server machine. For this, the service registers logs to the server machine.

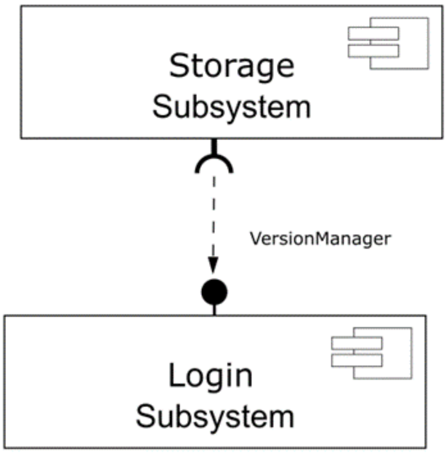

Figure 16: Representation of Update Service

Enforce the use of the stable version of the software

The system works at a reliable safety level. For this, any update from the developers must be applied to the product. Thanks to VersionManager service, each login attempt success at only a stable and required version.

5. Glossary

Session: Time interval between driving start and end.

Supervisor: The person is the administrative authority of the environment of the system. User: The person driving the car on the scene in a session

GUI: Graphical User Interface Authorization: Authorization is the function of specifying access rights/privileges to resources, which is related to general information security and computer security, and to access control in particular.

Authentication: Authentication is the process of determining whether someone or something is, in fact, who or what it declares itself to be.

Software Architecture: A high-level description of the system, including design goals, subsystem decomposition, hardware/software platform, persistent storage strategy, global control flow, access control policy, and boundary condition strategies. The system design model represents the strategic decisions made by the architecture team that allow subsystem teams to work concurrently and cooperate effectively.

6. References

1. Soukupova, T., & Cech, J. (2016). Real-Time Eye Blink Detection using Facial Landmarks.
2. Bruegge, B., & Dutoit, A. H. (2003). Object-oriented software engineering: Using UML, patterns and Java. Upper Saddle River, NJ: Prentice Hall.
3. Singh, A. & Chandewar, C. & Pattarkine, P. (2018). Driver Drowsiness Alert System with Effective Feature Extraction.
4. Driving Behaviors Reported For Drivers And Motorcycle Operators Involved In Fatal Crashes, 2018 from https://www.iii.org/fact-statistic/facts-statistics-drowsy-driving#:~:text=A
5. Pushpa Narayan | TNN | Jan 16, 2014, *IIT-M's wake-up call for tired drivers* ,Retrieved from https://timesofindia.indiatimes.com/city/chennai/IIT-Ms-wake-up-call-for-tired-drivers/articleshow/28869401.cms