THE UNIVERSITY OF DANANG
UNIVERSITY OF SCIENCE AND TECHNOLOGY
Faculty of Advanced Science and Technology

PBL3: ARTIFICIAL INTELLIGENCE FOR INTEGRATED SYSTEM AND APPLICATION

Topic: Drowsiness recognition

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Mentor : Ho Xuan Dat

Class : 21ECE

Group members : Nguyen Thi Tam
Tran Hoang Minh
Le Tu Bao Khanh

Da Nang, June 14th, 2024

INTRODUCTION

There are various reasons for road accidents. The main cause of road accidents is drowsy drivers. In recent years, technologies have been developed and various techniques have been created to detect and prevent traffic accidents. Based on vehicle, behavioral, and physiological approaches, or specifically in the behavioral-based approach, it has somewhat helped in recognizing the drowsiness status of drivers.

This project aims to develop a drowsy driver detection system using Raspberry Pi to enhance road safety and prevent accidents caused by driver fatigue. The system will be integrated with the vehicle's sound system and will utilize images.

The group has utilized AI technologies in face detection and recognition. However, there are still some shortcomings, so the system is not yet perfect. The group will continue to develop and improve it in the future.

ACKNOWLEDGEMENTS

With dedicated research and invaluable guidance from Associate Professor Dr. Pham Van Tuan, we have successfully completed this project. However, due to limited time and constrained knowledge, there may be some errors, and the system might not be optimized to its full potential. We kindly request our lecturer's understanding and support in providing further insights and guidance to enhance both the product and our comprehension of the subject matter. We sincerely thank Associate Professor Dr. Pham Van Tuan and teaching assistant Mr. Ho Xuan Dat for their support throughout the completion of this project. Their dedicated instruction and valuable feedback have significantly contributed to the quality of our report and enhanced our knowledge.

We hereby commit that the entire content of this report is the result of our group's diligent research and work. All sources of information and references have been fully and accurately cited. We assure you that no part of this work has been copied or used unlawfully from other sources without proper authorization. If any errors or violations are found, we take full responsibility and will rectify them in accordance with the school's regulations.

TASK OF MEMBER

Name of member	Task	Contribution
Tran Hoang Minh (Leader)	Training AI model Set up messages and tracking systems Set up the virtual environment, coding Debug as needed Write report	40%
Nguyen Thi Tam	Set up microSD, OS for Raspberry pi 4 and its modules in the project Evaluate and purchase component, research for image processing Calculate and write EAR (Eye Aspect Ratio) formula, algorithm. Test and record the process Write report	30%
Le Tu Bao Khanh	Research and evaluate python and its libraries Searching for solving the error Support Write report	30%

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DESIGN THINKING

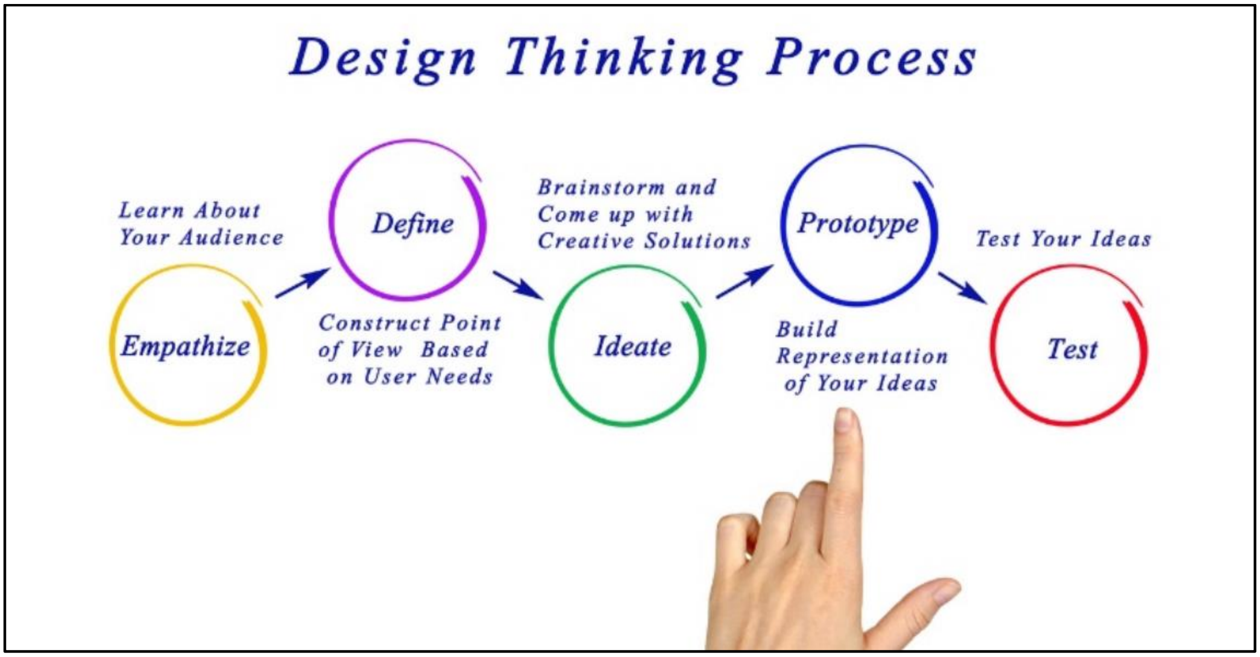


Figure 1: Design Thinking Process

Step 1: Empathize

The modus operandi of this method is to look for problems and solutions from the mindset of the person directly using the product.

⇨ It is necessary to learn more about the market through research, surveys and real experience in the customer's location.

⇨ Understand the potential difficulties and motivations of customers before the problem.

Step 2: Define the problem

The data and information collected in step 1 will be aggregated and linked together for analysis.

⇨ Identify the heart of the problem.

Step 3: Ideate (Create)

Use your thinking to generate creative ideas. From the information synthesized, you can start "thinking outside the box" to discover the most innovative and new solutions.

Step 4: Prototype

Through research, test run, and development based on actual user experience to gradually eliminate unsatisfactory products.

=> Based on the prototyping, you will be aware of the limitations and problems of the product from which to make effective improvements.

APPLY DESIGN THINKING IN THE PROJECT:

The problem: Car accidents caused by drowsiness drivers in Da Nang city damage life, property, and environmental impacts.

I. Stage Empathize

- Nowadays, there are many causes of car accidents such as: drivers' factor, vehicles, environment, etc.

1. Statics about car accidents

In 2022, (the reporting period is from December 15, 2021 to December 14, 2022), in the first 10 months of 2022, there were 9,212 traffic accidents nationwide, killing 5,221 people, and about 17 people dying in traffic accidents a day.(link). Among them, car accidents accounted for the highest proportion.

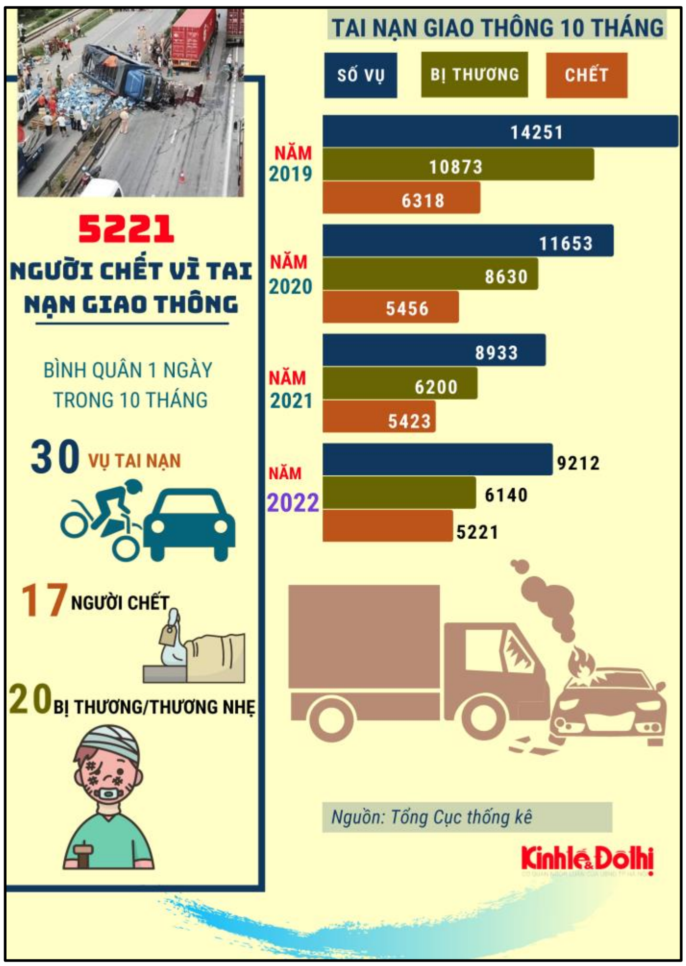


Figure 2: Statistic of accident in Vietnam

2. *Influence*

- Each year, traffic accidents in our country cause economic losses of VND 40,000-60,000 billion, affecting working life and social problems. (link1)
- Traffic accidents have caused losses of about 2.9% of the country's annual GDP. This is really a challenge, a burden on the task of ensuring social security as well as national development. (link2).
- The unfortunate victims passed away suddenly due to traffic accidents, leaving behind grief, shock, and great loss for their families and relatives.(link)

3. *Cause of problem*
- Deviating from the lane
- The distance is too close to another vehicle
- Frequent blinking
- The scene before eyes blurred

Figure 3: Drowsy driver

4. *Challenges*

   a. *Drivers:* Fatigue, sleep deprivation, medical conditions, medication side effects, individual susceptibility to drowsiness.

b. *Vehicles:* Monotonous driving environments, uncomfortable seating, poor lighting, lack of driver engagement features. Cars technical problem.

c. *Environment:* Long journeys, late-night driving, hot or cold temperatures, traffic conditions, bad weather.

⇨ *Evidence*:

- A 2018 survey from the AA found that a quarter of 8 (13%) UK drivers admitted to falling asleep at the wheel. Nearly two-fifths (37%) say they are too tired and afraid that they will fall asleep while driving.

- American researchers concluded that driving after just 5 hours of sleep is as dangerous as drunk driving. The only antidote to drowsiness is sleep, so take time to drive when you're normal and awake. If you are sleepy, stop and take a 20-minute nap and continue driving to ensure the safety of yourself and other road users. (link)

d. *Conclusion*: In Vietnam, car accidents are a critical problem. One of the most reasonable problems is drowsy driving.

⇨ As a result, our aim is a solution to aid drivers in avoiding falling asleep while driving.

II. Stage Define

Name Group	Activity 1 - Team forming		Activity 2 - Personal Creating	Activity 3 - Problem Identification - 03 Selected interested problems & WHERE - WHO - HOW to identify real needs
Group 4 - 21ECE	Name of members	Nguyen Thi Tam	https://drive.google.com/file/d/1DzgetwkfMpoADp0_4ZJziBPT2539JNIZ/view?usp=sharing	Problem 1: Car accidents Where: Da Nang's roads Who: Drivers and people living nearly How: Increase in accidents risks, harmful impact on environment.
		Tran Hoang Minh	https://linkbio.co/6011407s98OgR	Problem 2: Cyberbullying Where: Social media networks Who: People who use social media apps How: Social isolation, impact harmfuly on social relationship
		Le Tu Bao Khanh	https://drive.google.com/file/d/1ncXNqk04PsPOrxMBUrGhoJ4HFuWsI2_z/view?usp=drive_link	Problem 3: Parking problem Where: Da Nang city Who: Everyone join in traffic How: Traffic congestion, time consuming

Table 1,2,3: Team forming – Person creating - Problem Identification

Activity 4 - Problem Identification - 03 Selected interested problems and WHERE - WHO - HOW to identify real needs 01 Selected interested problem		
Problem : Car accidents Where: Da Nang's roads Who: Drivers How: Increase in accident rates, damage to life, property, fire and explosion and environmental impacts ...	Inputs	- Physiological Signals: Data such as heart rate, respiration rate, electrodermal activity, and eye movements provide valuable insights into the user's physiological state. - Video Images: Analyzing facial expressions, eye behaviors, and head movements from video footage can offer additional cues for detecting fatigue and drowsiness. - Vehicle Data: Information related to vehicle dynamics, such as steering wheel movements, lane position, and vehicle speed, can be indicative of driver fatigue or impairment.
	Outputs	- Alerts: Providing timely alerts to the user or relevant authorities when signs of fatigue or drowsiness are detected to prevent accidents. - Feedbacks: Offering feedback to the user, such as suggestions for taking breaks, adjusting driving behavior, or seeking medical attention if necessary. - Data Logs: Recording and storing data logs for later analysis, reporting, or forensic purposes to understand patterns of fatigue and drowsiness and improve future monitoring systems.
	Conditions	- Popularization: Designing monitoring devices that are comfortable to use in almost every kind of car.
	Requirements	- Effectiveness: The system should significantly reduce injuries, fatalities, and property damage. - Reliability: The system must function consistently under various conditions. - Affordability: The solution should be cost-effective and implementable on a wide scale. - User friendliness: The system should not create additional burden or confusion for drivers.
	Constraints	- Legal and regulatory frameworks: Regulations governing autonomous vehicles and safety features. - Public acceptance: Willingness of drivers and passengers to trust technology-based solutions.

Table 4: Problem Identification

Activity 5 - Stakeholder Profile development			Activity 6 - User need list			
Person	**Description (Mô tả về stakeholder)**	**Photo**	**Need**	**Stakeholder**	**Need list**	**Common list**
Luong Nhu Quynh	Address: 91 Huynh Ngoc Hue Occupation: Student SDT: 0948941608		Dissipate the fatigue of drivers when driving	Luong Nhu Quynh	- Simplicity: easy using for people cannot use high technology - Safety: The methods should not distract drivers or take their attention away from the road. - Adjustable: User can adjust the music of the alarm themselves	- Simplicity: easily use for people regareless of the age - Safety: The devices should not distract drivers - Flexibility: User can adjust the sounds of the alarm, music by themselves - Ability: work in diverse environmental conditions regardless of the difference in temperature - Durability and stability: hard to be broken and long lasting - Affordable prices: should be < 2m - Compact for drivers
Doan Thi Dieu Hien	Address: 113 Nguyen Son Occupation: Student SDT: 0916134437		Decrease the drowsiness of drivers when driving	Doan Thi Dieu Hien	- Affordable prices - Integrated in dashcam - Engage in conversation by audio book or podcasts	
Le Dinh Nhat Khanh	Address: 82 Nguyen Huu Tho Occupation: Student SDT: 0905980285		Improve the sanity of drivers when driving	Le Dinh Nhat Khanh	- Automatic adjust the car custom - Light - Suitable with type SUV car	

Table 5,6: Stakecholder profic development – user need list

III. Stage Idea

1. *Input*

   - *Physiological Signals:* Data such as heart rate, respiration rate, electrodermal activity, and eye movements provide valuable insights into the user's physiological state.
   - *Video Images:* Analyzing facial expressions, eye behavior, and head movements from video footage can offer additional cues for detecting fatigue and drowsiness.
   - *Vehicle Data:* Information related to vehicle dynamics, such as steering wheel movements, lane position, and vehicle speed, can be indicative of driver fatigue or impairment.

2. *Constraint conditions*

   - *Cost:* Developing affordable monitoring solutions accessible to a wide range of users is essential for widespread adoption.
   - *Popularization:* Designing monitoring devices that are comfortable to use in almost every kind of car.

3. *Technical problems*

   - *Sensor accuracy:* Ensuring that sensors used to monitor physiological signals (camera) are accurate and reliable is crucial. Inaccurate sensor readings could lead to false alarms or missed detections of fatigue.
   - *Algorithm performance:* These algorithms should be sensitive enough to detect subtle signs of fatigue while minimizing false positives.
   - *Power consumption:* Optimizing power usage to prolong battery life without compromising monitoring accuracy is a key consideration.

4. *Outputs*

   - *Alerts:* Providing timely alerts to the user or relevant authorities when signs of fatigue or drowsiness are detected to prevent accidents.

- *Feedback:* Offering feedback to the user, such as suggestions for taking breaks, adjusting driving behavior, or seeking medical attention if necessary.

- *Data Logs:* Recording and storing data logs for later analysis, reporting, or forensic purposes to understand patterns of fatigue and drowsiness and improve future monitoring systems.

⇨ ***Common list:***

- Simplicity: easily use for people regareless of the age
- Safety: The devices should not distract drivers
- Flexibility: User can adjust the sounds of the alarm, music by themselves
- Ability: work in diverse environmental conditions regardless of the difference in temperature
- Durability and stability: hard to be broken and long lasting
- Affordable prices: should be < 2m
- Compact for drivers

Activity 8 - Existing commercial products and solutions		Reference Products
Name	Solutions	
VinAI	- Maintain a safe driving experience through in-cabin solutions. - Using high-performance cameras and AI to analyze driver behavior patterns and prevent driving errors. - The system is adaptable and integrates with multiple hardware platforms, allowing manufacturers to optimize switching costs.	Driver and Occupants Monitoring System - VinAI
Honda	- The angle sensor monitors the degree of driver steering-wheel corrections, which will notify the driver if it detects excessive correction activity. - The system will automatically switch to an alternate screen whenever it determines that the driver isn't paying attention. - It will display one or two bars and a message informing them to take a break. If the detected level of attention grows worse, the system will produce a more noticeable visual warning. - It will give an audio alert and vibrate the steering wheel to encourage driver attention.	x
Ford	- This driver assistance system uses a forward-facing camera mounted in the instrument cluster to detect whether the driver's eyes are open or closed and in which direction the driver is looking. - The system can determine whether a driver is too close to an object ahead to brake safely. If the driver doesn't respond after multiple alerts over several seconds, the control system with collision warning will automatically engage emergency braking to help avoid or reduce impact.	What is the Driver Alert System? (ford.com)

Table 7: Existing commerical products and solution

Activity 9 - Technical Solutions				
Name	**Solutions**	**Note**	**Strengths**	**Weakness**
Fatigue and Drowsiness Monitoring	- Apply sensors that monitor physical signs of fatigue such as drownsiness or unnatural movements of drivers. - Detect when the drivers lose focus or show signs of drowsiness and issue warnings through sound, vibration, or messages on the car display.	Link image	- Enhance Safety: Prevent accidents caused by tired or distracted drivers by monitoring physical signs of fatigue and detecting drowsiness. - Customized Alerts: By utilizing different modes of alert such as sound, vibration, or messages on the car display, these solutions can cater to drivers's preferences and ensure that drivers receive the most effective warnings.	- Integration Challenges: Integrating fatigue monitoring systems into existing vehicles or fleets may pose technical challenges, such as older vehicles that lack the necessary infrastructure. Apllication these systems into older vehicles can be costly and may require modifications to the vehicle's interior or electrical systems. - Driver Discomfort or Distraction: The alerts issued by fatigue monitoring systems, such as sound, vibration or messages on the car display, may cause driver discomfort when they are driving.
Driver Attention Monitor	- The system should utilize radar sensors to monitor the distance between vehicles and surrounding obstacles. - Detect potential collision risks and alert the drivers through audio or visual warnings. - Integrate with automatic braking systems to minimize casualties when necessary.		- Reduced Human Error: By providing timely warnings and autonomous braking interventions, they compensate for lapses in driver attention or judgment, reducing the likelihood of accidents caused by human mistakes. - Collision Prevention: By continuously monitoring the distance between vehicles and surrounding obstacles, it can detect potential collision risks well in advance leading to prevent accidents before they occur.	- False Alarms: Radar sensors can sometimes generate false alarms owing to environments with high levels of electromagnetic interference or where there are reflective surfaces that can bounce signals, leading to driver distraction, reducing the system's overall effectiveness. - Detection Range Limitations: Radar sensors typically have a limited detection range which may result in a reduced ability to detect distances between vehicles and obstacles or increase the risk of collisions at higher speeds or on highways where objects can enter the vehicle's path rapidly.

Table 8: Technical solutions

IV. Stage Prototype:

Activity 7: Gantt Chart Development				
Time	Gantt Chart Development		Period	
	Task	Team member	Start day (Sunday)	End day (Saturnday)
Week 25	Review information about subject and syllabus	All	14/01/2024	20/01/2024
Week 26	**Overview of Machine Learning for Integrated Systems & Applications**		21/01/2024	27/01/2024
	CURRENT issues	Minh, Tam		
	TRENDS in AI's applications	Khanh		
Week 27-29	***Tet's Holiday***		*28/01/2024*	*17/02/2024*
Week 30	**Design Thinking**		18/02/2024	24/02/2024
	Define 5 steps of Design thinking	All		
	Implement step E and D			
	Stage Empathize	Minh		
	Stage Define	Khanh, Tam		
Week 31	***Off***		*25/02/2024*	*02/03/2024*
Week 32	Team name	All	03/03/2024	09/03/2024
	Members's Role	All		
	Team update	All		
Week 33	Problem Identification	All	10/03/2024	16/03/2024
	Specification Development	All		
	Interview Scenarios	All		
	Conduct interviews	Note: Tam Interviewer: All Videographer, photographer: Minh, Khan		
	Stakeholder Need	Designer:Minh, Khanh Informant: Tam		
	User need list	Khanh, Tam		
	Grant chart	Tam		
	PESTLE Analysis	All		
Week 34	Conceptual Design	All	17/03/2024	23/03/2024
	Detailed Design	All		
Week 35	Detailed Design: Functional design	Khanh, Tam	24/03/2024	30/03/2024
	Detailed Design: Design principle	Minh		
	Detailed design review	All		
Week 36	***Midterm***		31/03/2024	06/04/2024
Week 37-38	Building	All	07/04/2024	20/04/2024
	Evaluation criteria	Minh		
	Evaluation Scenario	Tam		
	Evaluation Participants	Khanh		
Week 39-40	Testing	All	21/04/2024	27/04/2024
			28/04/2024	04/05/2024
Week 41	Make a report+slide	All	05/05/2024	11/05/2024
	Presentation rehearsals			
Week 42	Final rehearsals	Presentation: All	12/05/2024	18/05/2024

Table 9: Gantt chart

1. *Hardware*

- Input: The webcam captures video data as input for the system.
- Process: The Raspberry Pi processes the video frames to detect signs of drowsiness.
- Output: An audio alert is played through the speaker if drowsiness is detected. We will have a small PC speaker, powered by USB. Note that if you connect audio to the AUX port of the car audio system, you do not need these PC speakers.

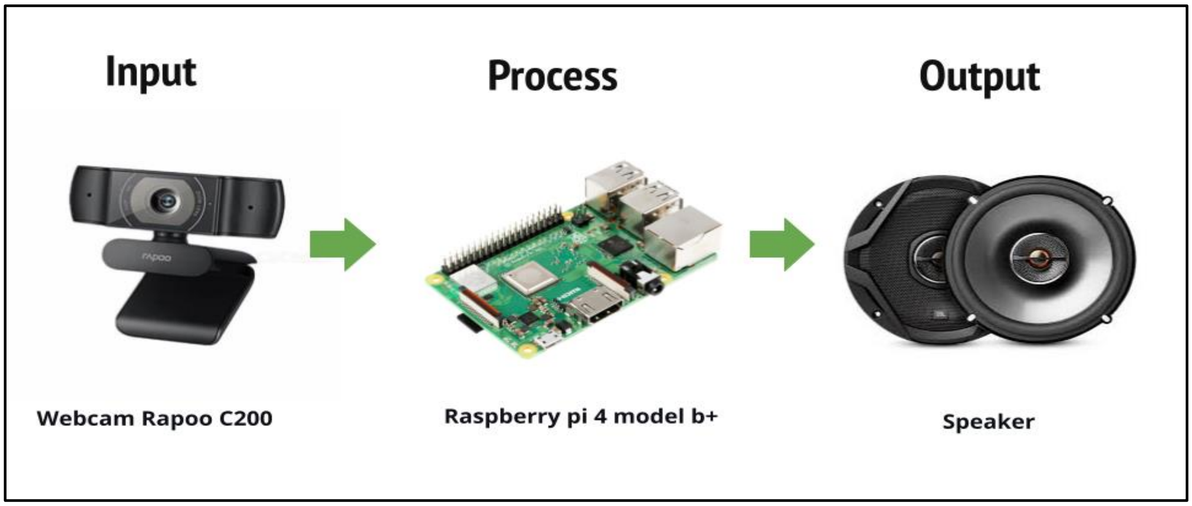


Figure 4: Hardware diagram

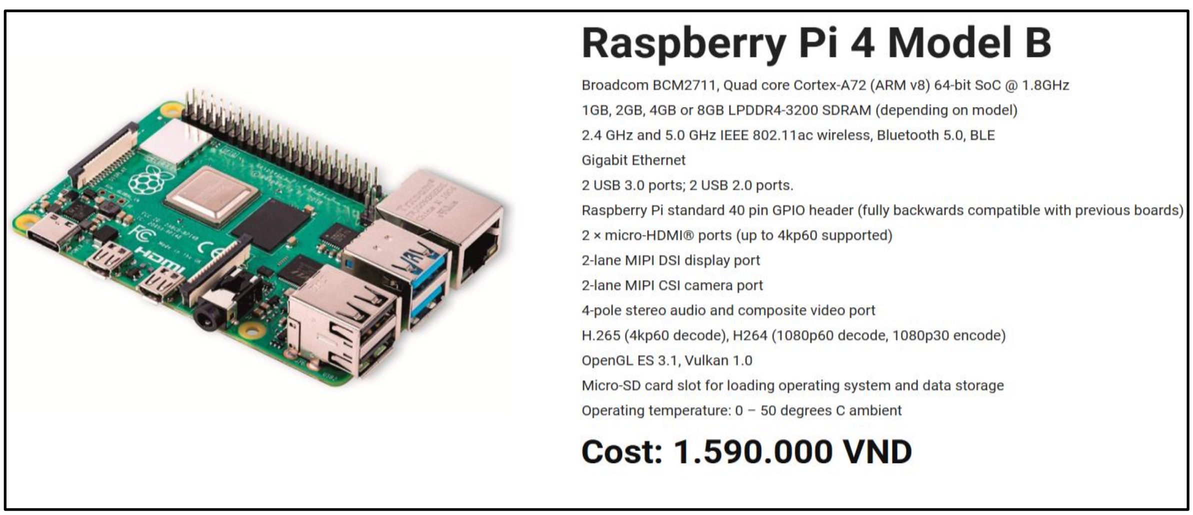


Figure 5: Raspberry Pi 4 Model B

Figure 6: USB camera Rapoo C200

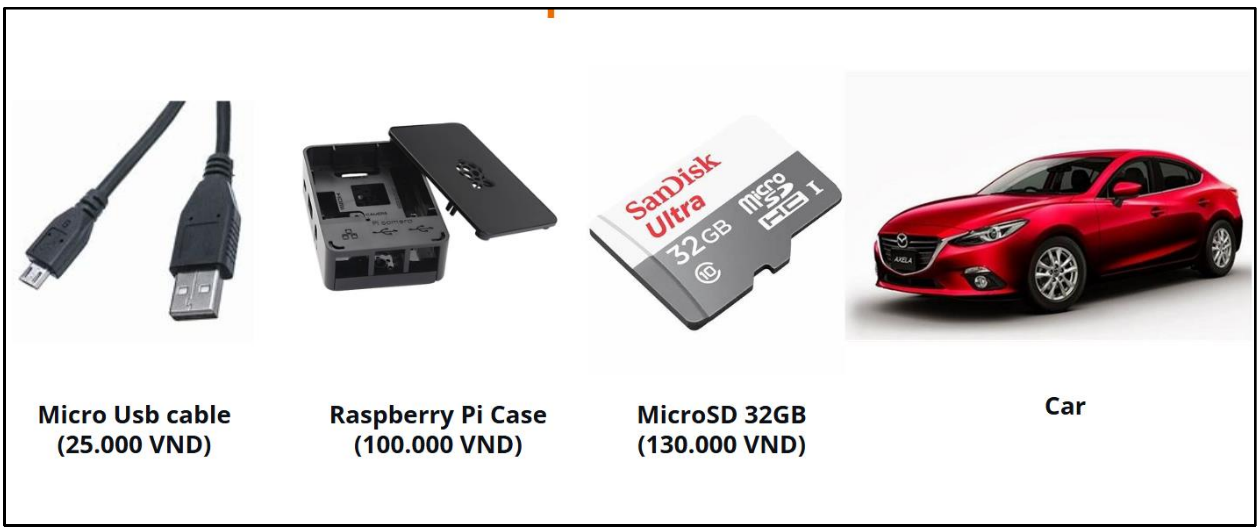


Figure 7: Components

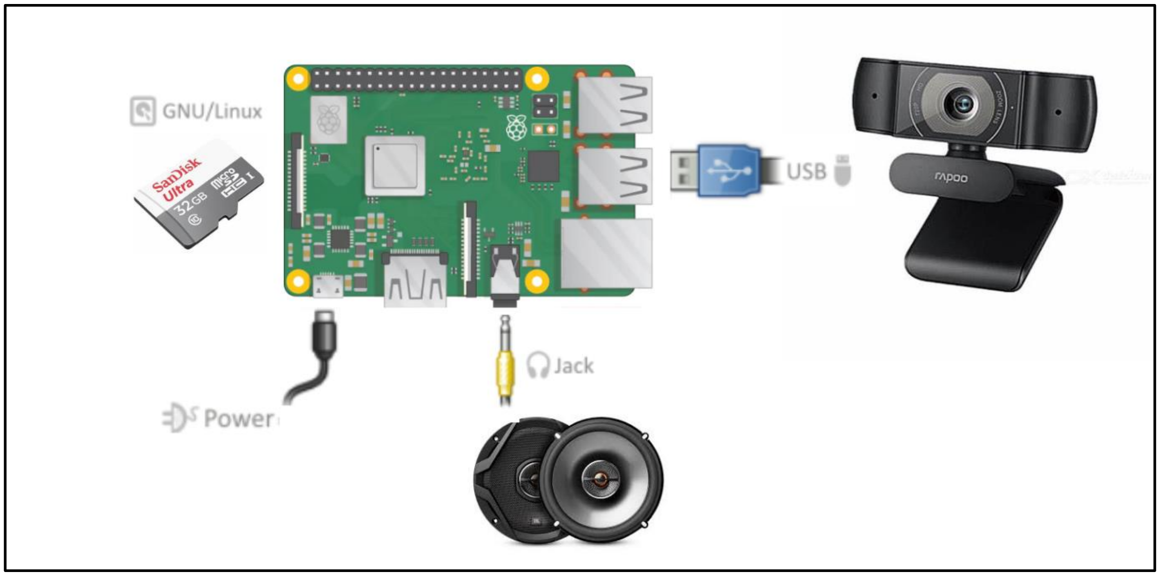


Figure 8: Set up diagram

Figure 9: Set up in a car

2. *Software: Python, OpenCV, Dlib, Imutils, Numpy, Firebase*

   a. *Python*

      - Python is a high-level, interpreted programming language known for its readability, simplicity, and versatility. It supports multiple programming paradigms and is widely used in web development, data analysis, scientific computing, artificial intelligence, and automation.

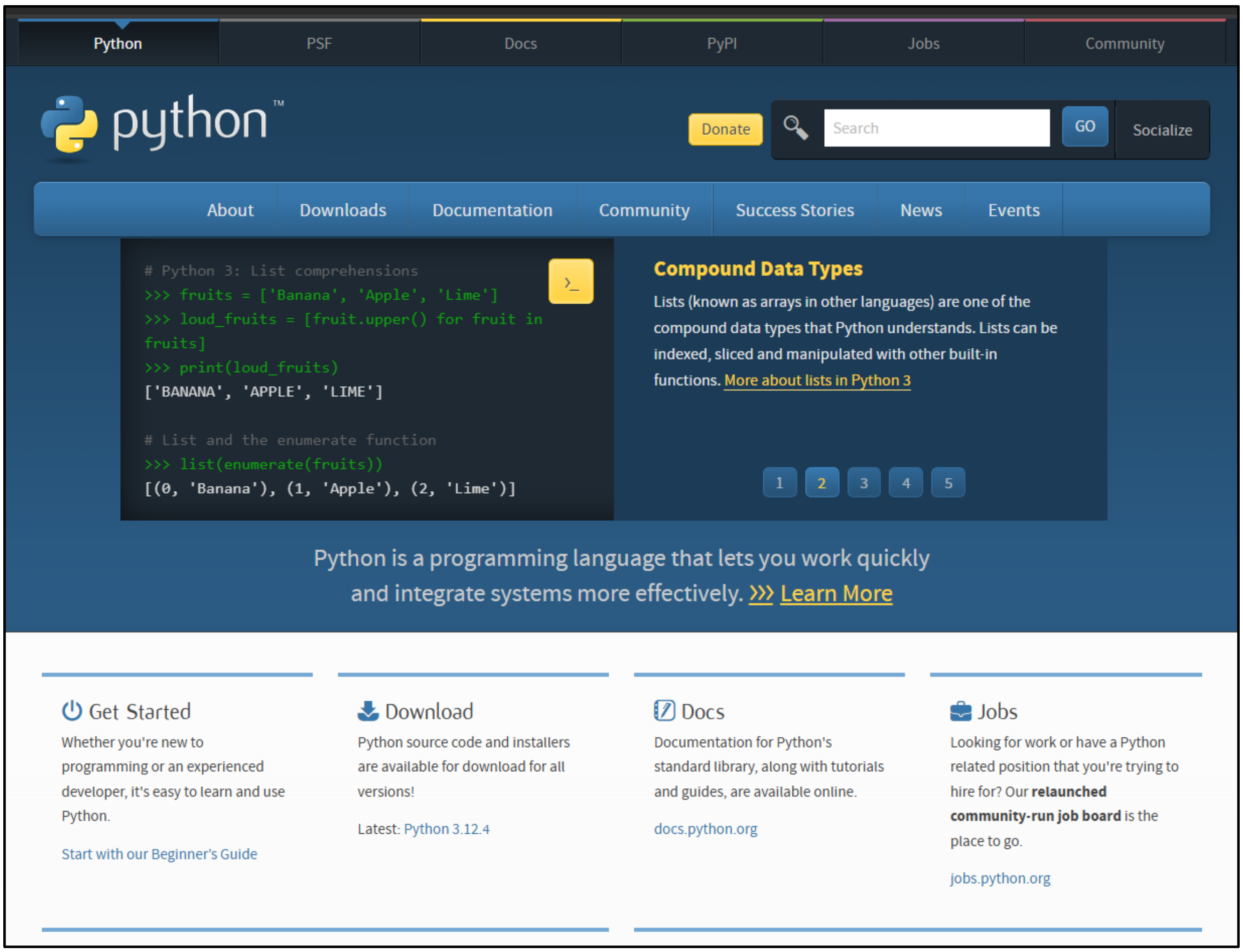


Figure 10: Python website

   b. *OpenCV*

      - OpenCV (Open-Source Computer Vision Library), an open-source software library that provides a wide range of tools and functions for computer vision and image processing.

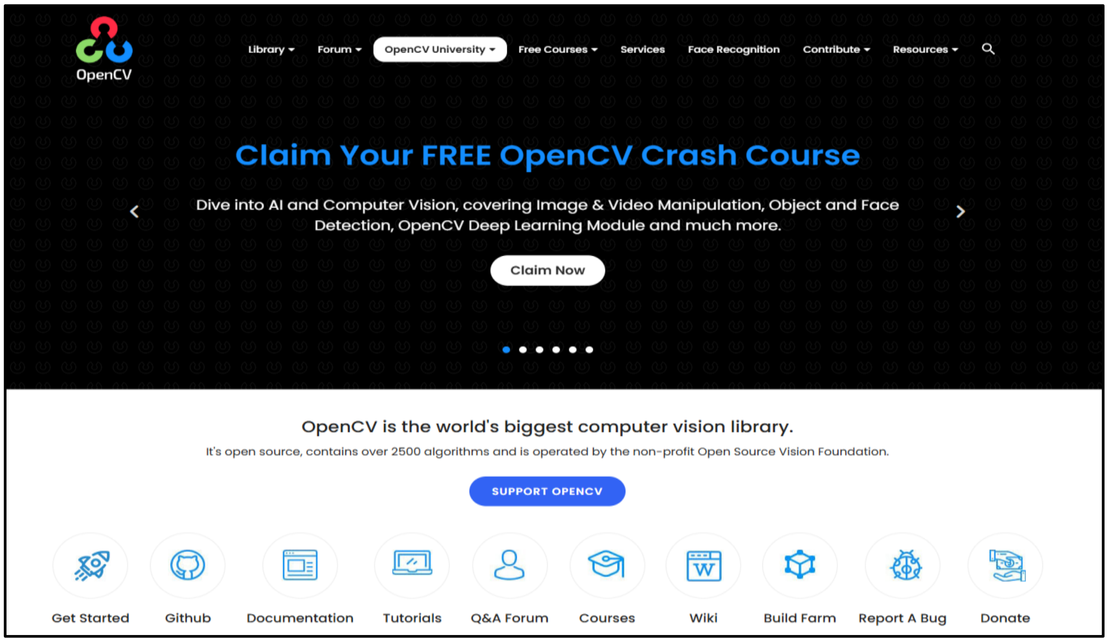


Figure 11: OpenCV website

c. *Dlib*

- Dlib is an open-source machine learning library that provides tools for tasks such as facial recognition, object detection, and image processing.

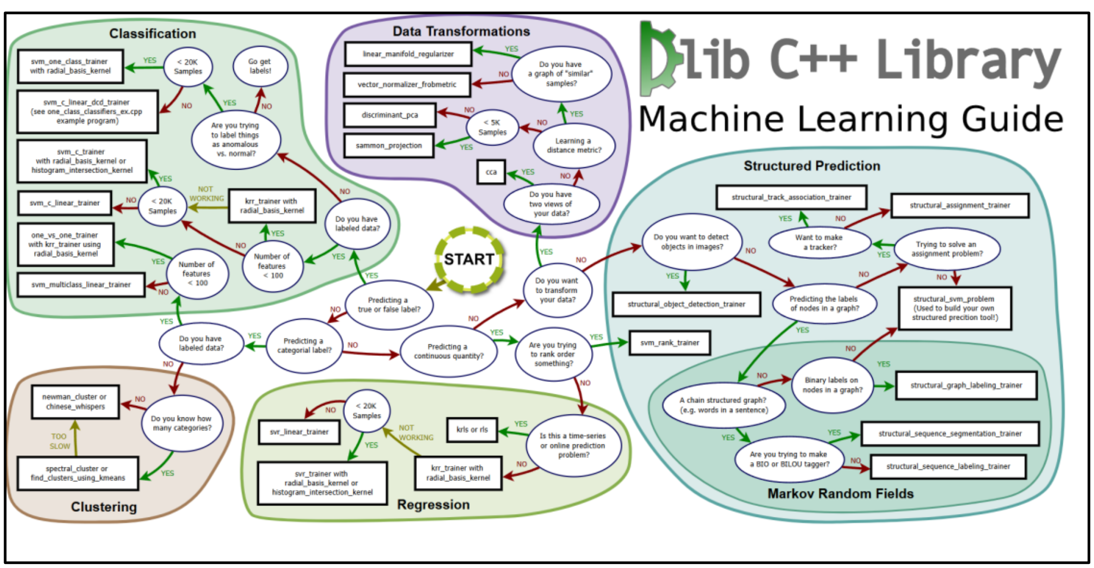


Figure 12: Dlib C++ librabry overview

d. *Firebase*

- Firebase is a mobile application development platform from Google that helps developers build, improve, and grow their apps. It offers a variety of tools and services to streamline the development process.

Figure 13: Firebase overview

e. *Thunkable*

- Thunkable is a platform that lets you create mobile apps without needing to write code. It uses a drag-and-drop interface with pre-built components, making it accessible for beginners and those with no coding experience.

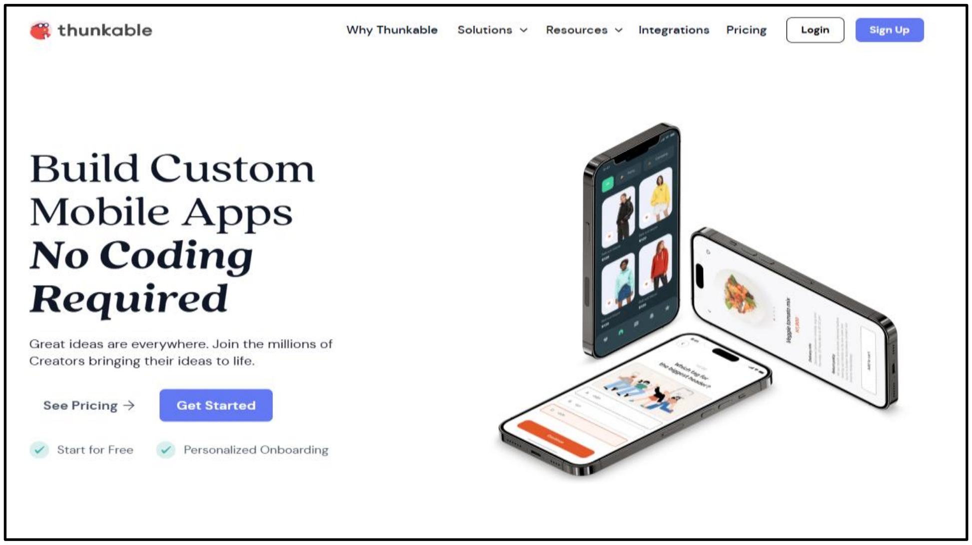


Figure 14: Thunkable website

f. *Whatsapp*

- WhatsApp from Meta is a FREE messaging and video calling app. It’s used by over 2 billion people in more than 180 countries. It’s simple, reliable, and private, so you can easily keep in touch with your friends and family. WhatsApp works across mobile and desktop even on slow connections, with no subscription fees.

Figure 15: Whatsapp overview

- You can use CallMeBot API to send WhatsApp text messages from your program, scripts, home automation, IoT devices, etc. Only one http GET is enough to send a WhatsApp message to your mobile phone.

Figure 16: CallMeBot API overview

3. *Functionality:*
   - *Digital image processing*
     - Digital image processing involves the use of computer algorithms to perform operations on digital images. It aims to enhance, analyze, and manipulate images for tasks such as improving quality, extracting information, and recognizing patterns.
   - *Adaboost*
     - AdaBoost (Adaptive Boosting), a machine learning algorithm that combines multiple weak classifiers to form a strong classifier. It works by sequentially training weak classifiers, each focusing more on the mistakes of its predecessor. The final model is a weighted sum of these weak classifiers, resulting in improved accuracy and performance.

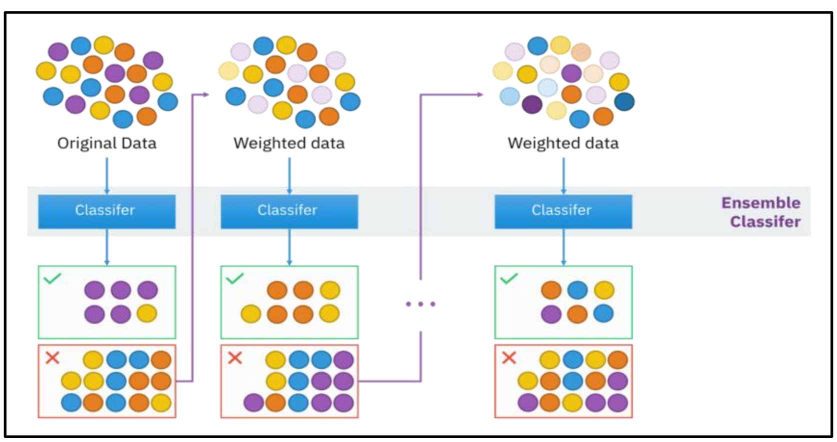


Figure 17: Adaboost overview

- *Haar-cascade*
    - Haar-cascade is a machine learning-based object detection algorithm that uses a series of stages, each with increasingly complex Haar-like features, to efficiently and accurately detect objects in images or video. That said, Haar cascades are:
        - An important part of the computer vision and image processing literature
        - Still used with OpenCV
        - Still useful, particularly when working in resource-constrained devices when we cannot afford to use more computationally expensive object detectors

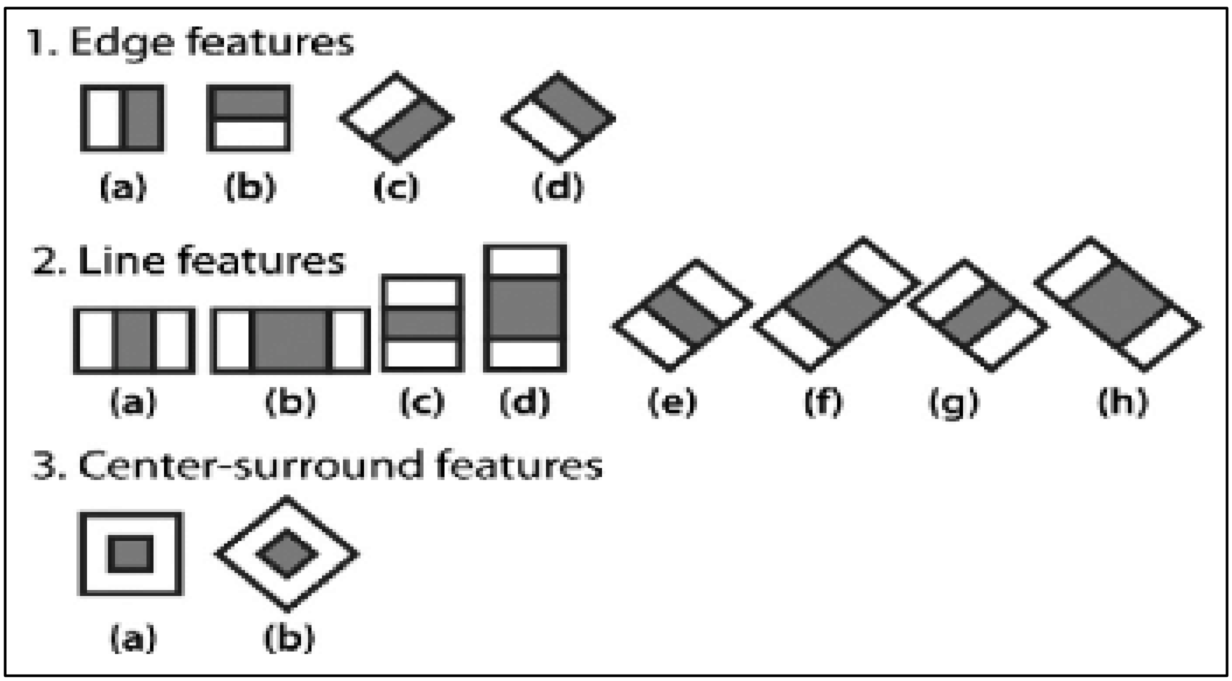


Figure 18: The different types of Haar-like features extracted from an image patch.

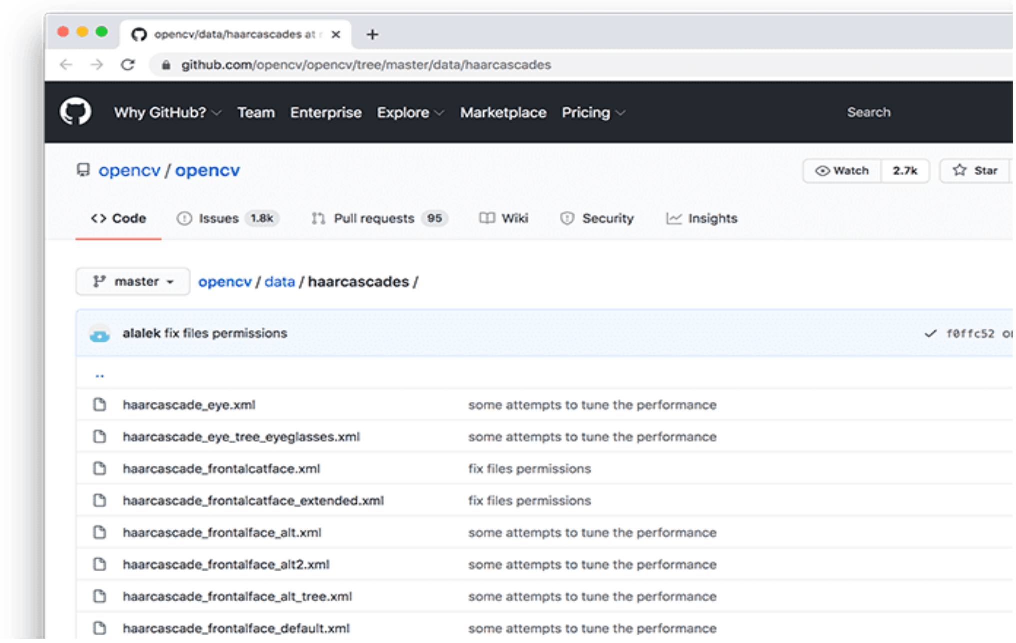


Figure 19: The official OpenCV GitHub maintains a repository of pre-trained Haar cascades.

- *Euclidean distance*
    - Euclidean distance is a measure of the straight-line distance between two points in Euclidean space. It is calculated as the square root of the sum of the squared differences between corresponding coordinates of the points.

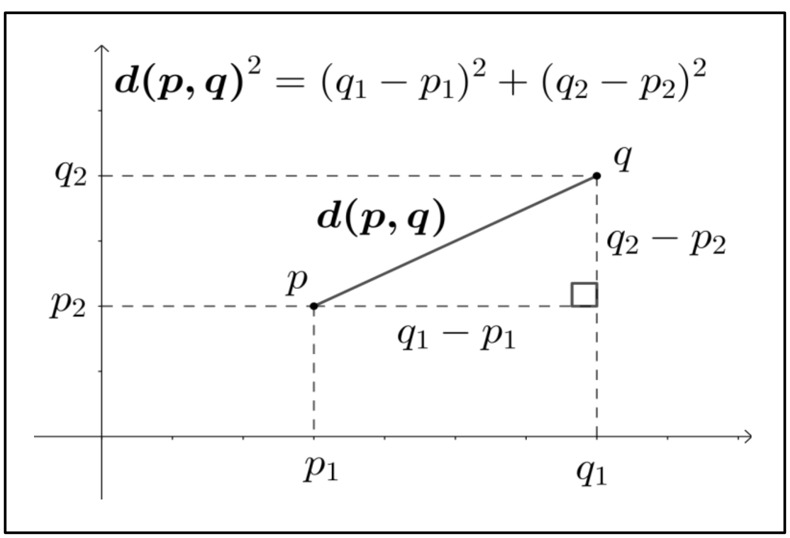


Figure 20: Euclidean distance

- The Euclidean distance may also be expressed more compactly in terms of the Euclidean norm of the Euclidean vector difference

$$d(p,q) = \|p - q\|.$$

- *Facial landmark*
  - Facial landmark refers to specific, predefined points on a face, such as the corners of the eyes, tip of the nose, and corners of the mouth. It is used to identify and analyze facial features.
- *Dataset*
  - From there we'll review the iBUG 300-W dataset, a common dataset used to train shape predictors used to localize specific locations on the human face (i.e., facial landmarks). iBUG 300-W consists of 300 Indoor and 300 Outdoor in-the-wild images. It covers a large variation of identity, expression, illumination conditions, pose, occlusion and face size.

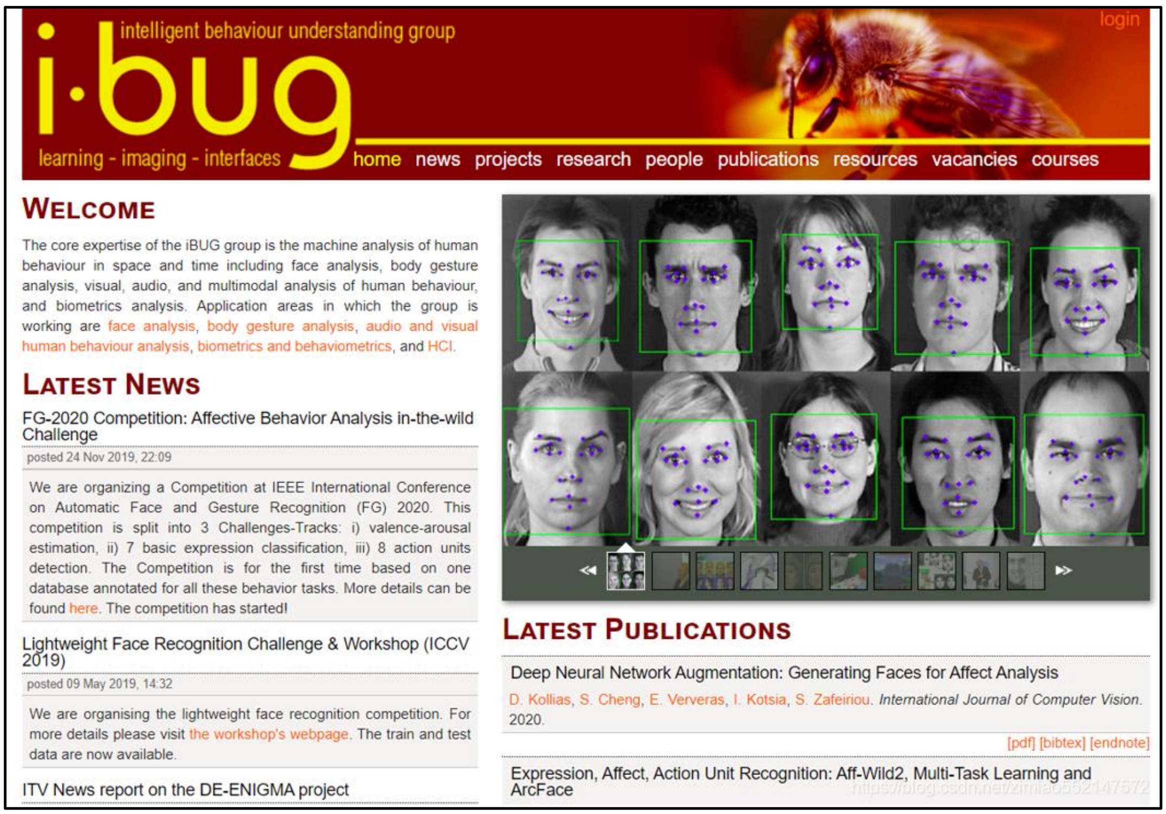


Figure 21: iBUG 300-W dataset website

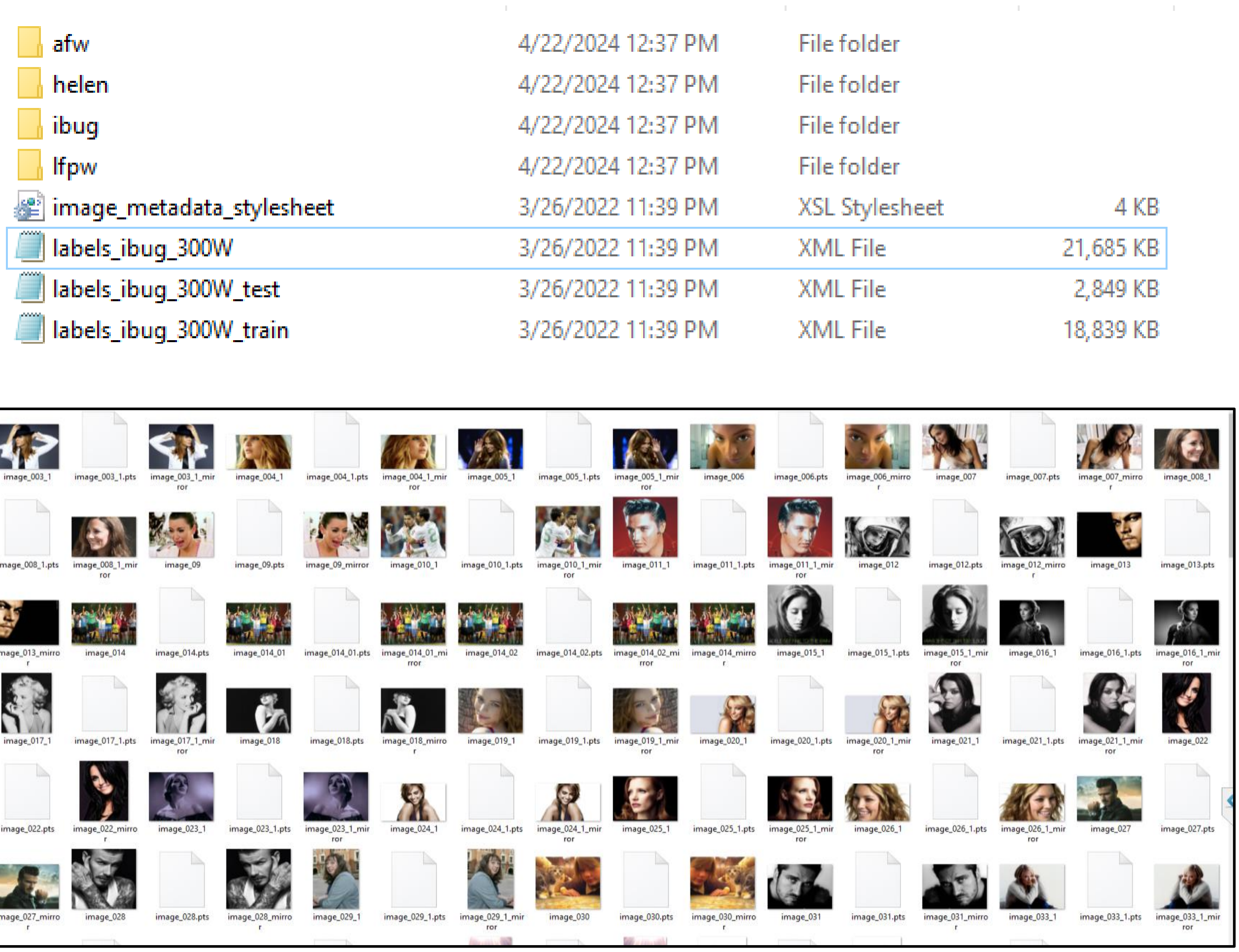


Figure 22: iBUG 300-W dataset

- *AI model*
    - Facial landmarks are a subset of the shape prediction problem. Given an input image (and typically a ROI denoting the object of interest in the image), a shape predictor attempts to localize landmark points on the shape. The goal is to detect the important facial structures on the face using shape prediction methods.
    - The process of facial landmark detection is a two-step process
        - Face localization: We can use the Haar Cascade algorithm built into OpenCV.
        - Facial structure detection: Once the face is localized, the next step is to detect the major facial structures within the ROI.

- Once we have the face region, we can apply Step 2 to detect the main facial structures in the face region. There are many facial feature marker detectors, but all methods mainly try to locate and label the following facial areas: Mouth, right eyebrow, left eyebrow, eyes right eye, left eye, nose, jaw. The facial landmark detector in the dlib library is a documented implementation One Millisecond Face Alignment with an Ensemble of Regression Trees

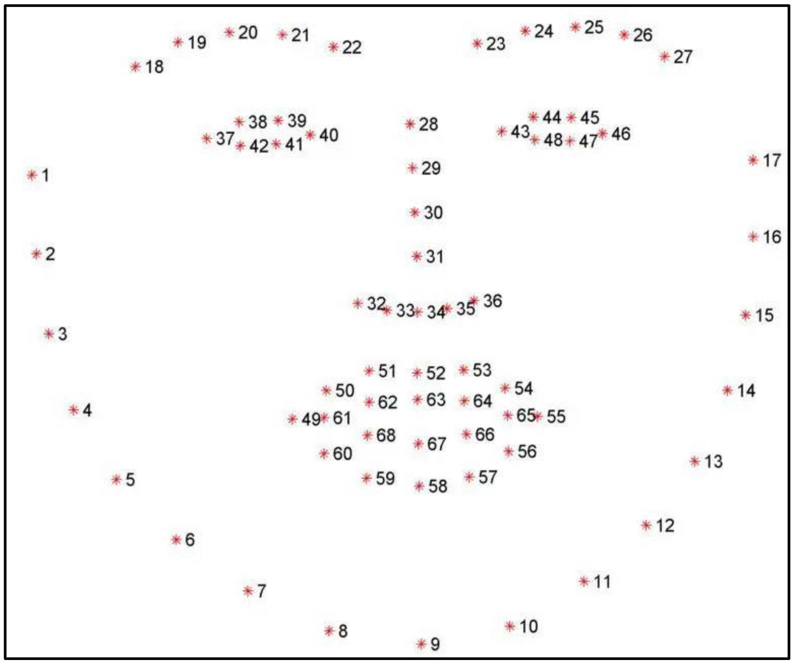


Figure 23: Visualizing the 68 facial landmark coordinates from the iBUG 300-W dataset.

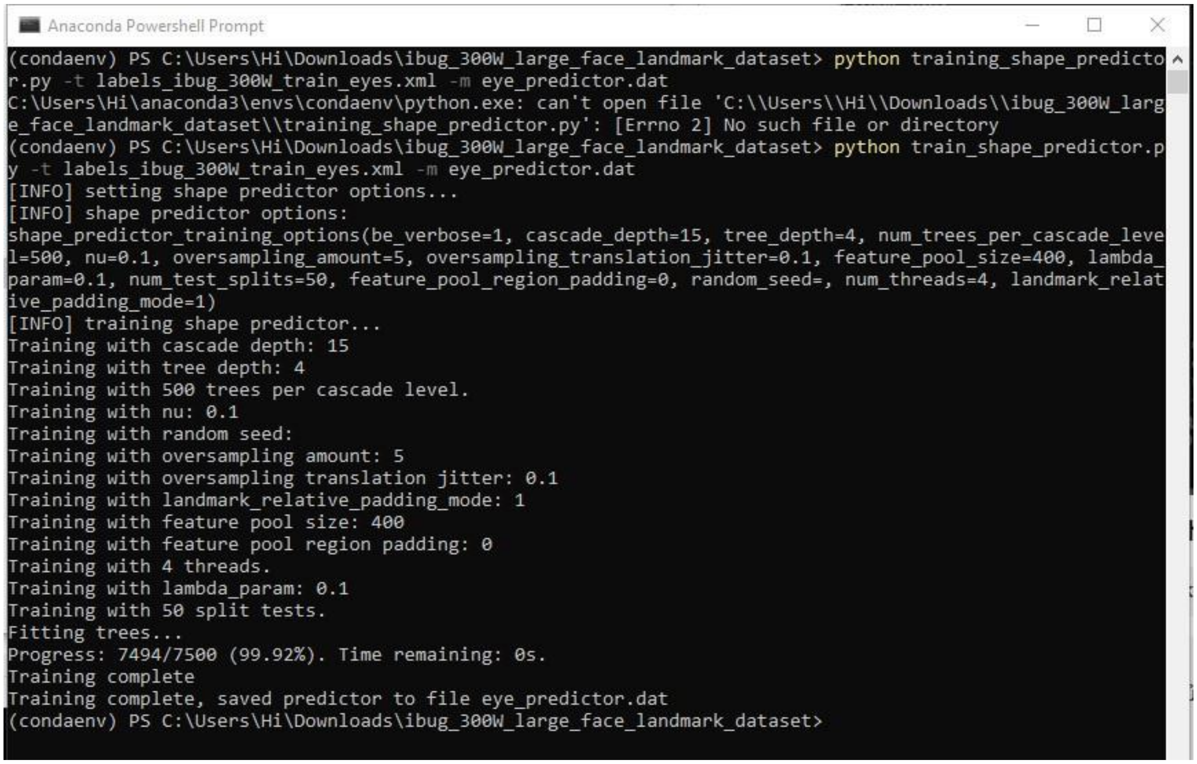


Figure 24: Building an "eyes only" shape predictor dataset

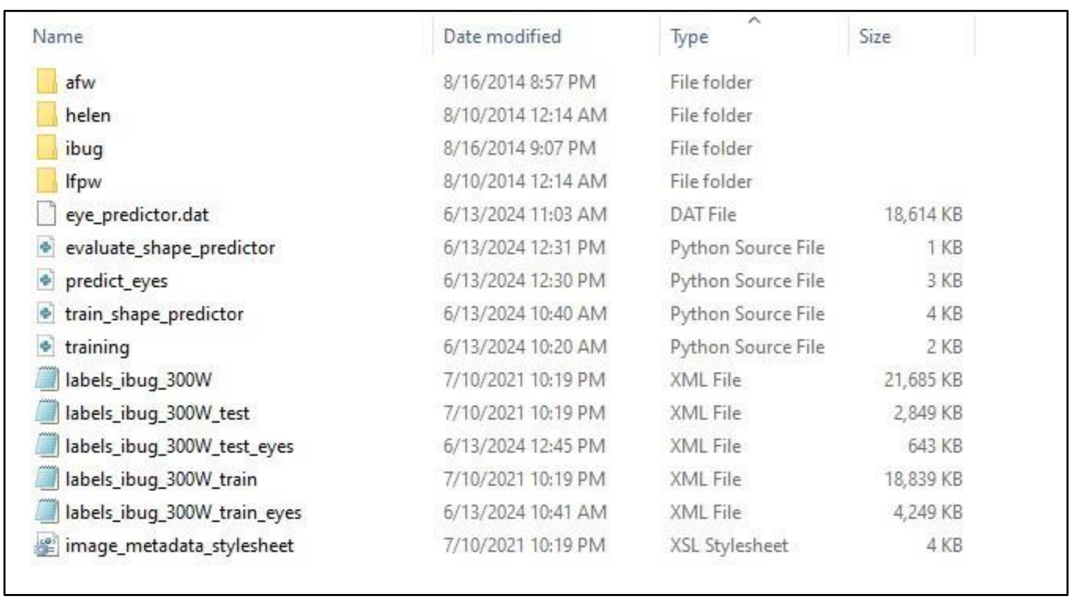


Figure 25: Our "eye only" face landmark training/testing XML files and training a dlib custom shape predictor with Python.

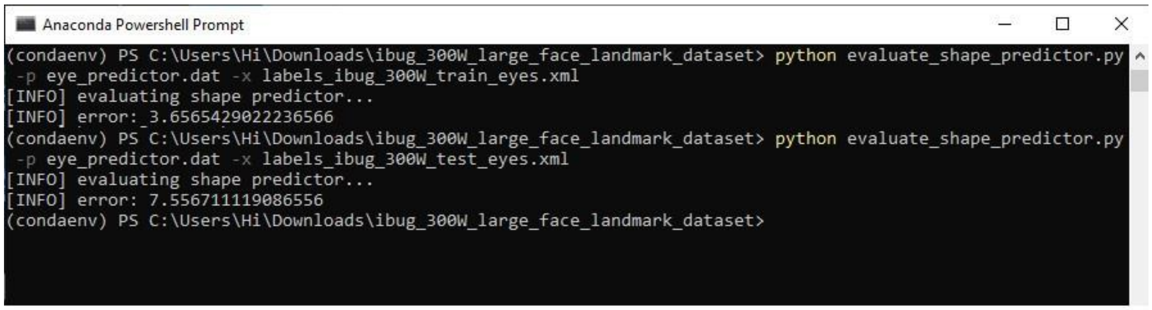


Figure 26: Shape prediction accuracy results

4. *Contribution*
   a. *Block diagram*

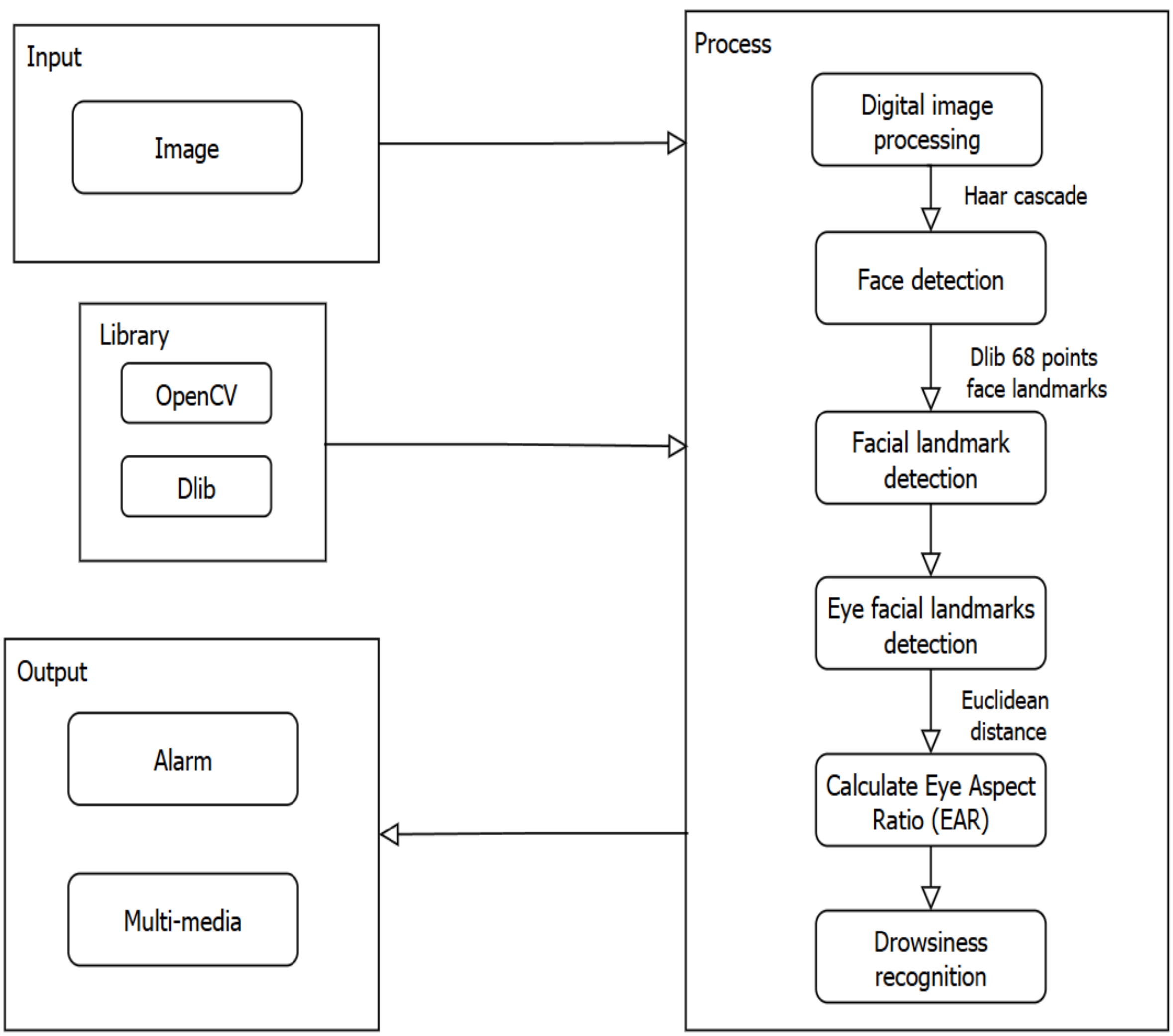


Figure 27: Block diagram of system

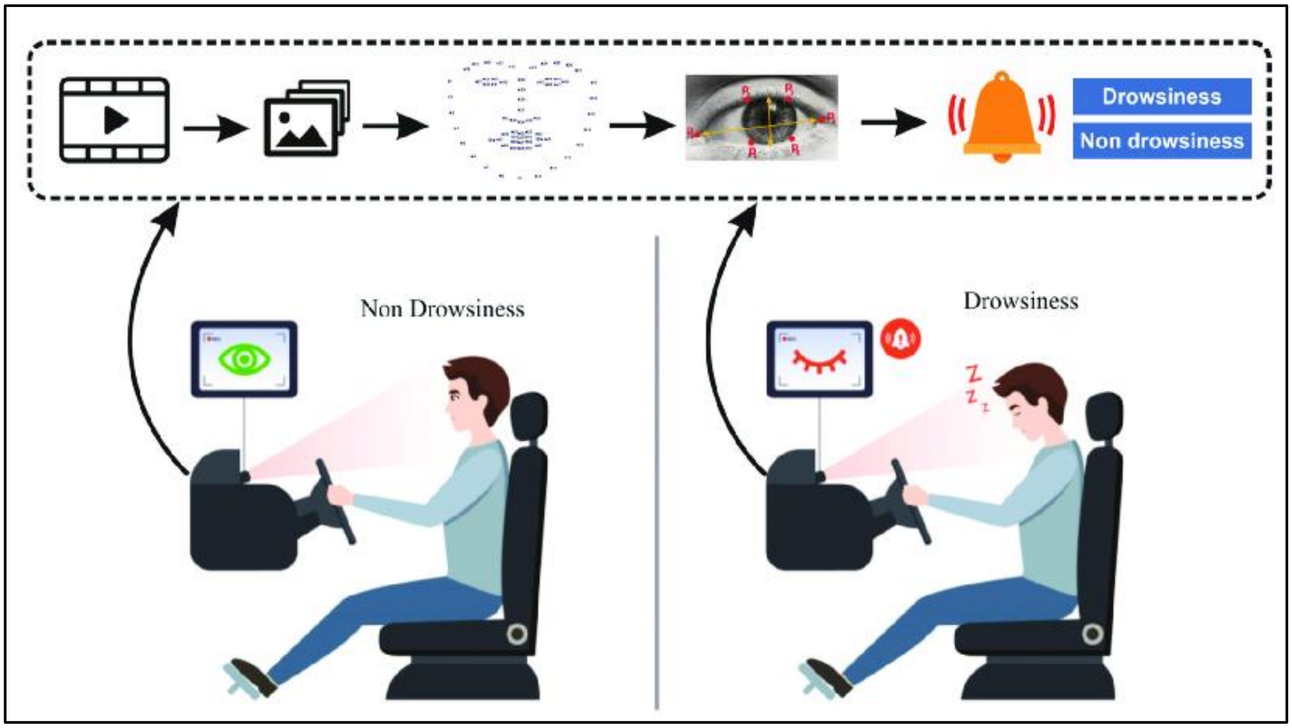
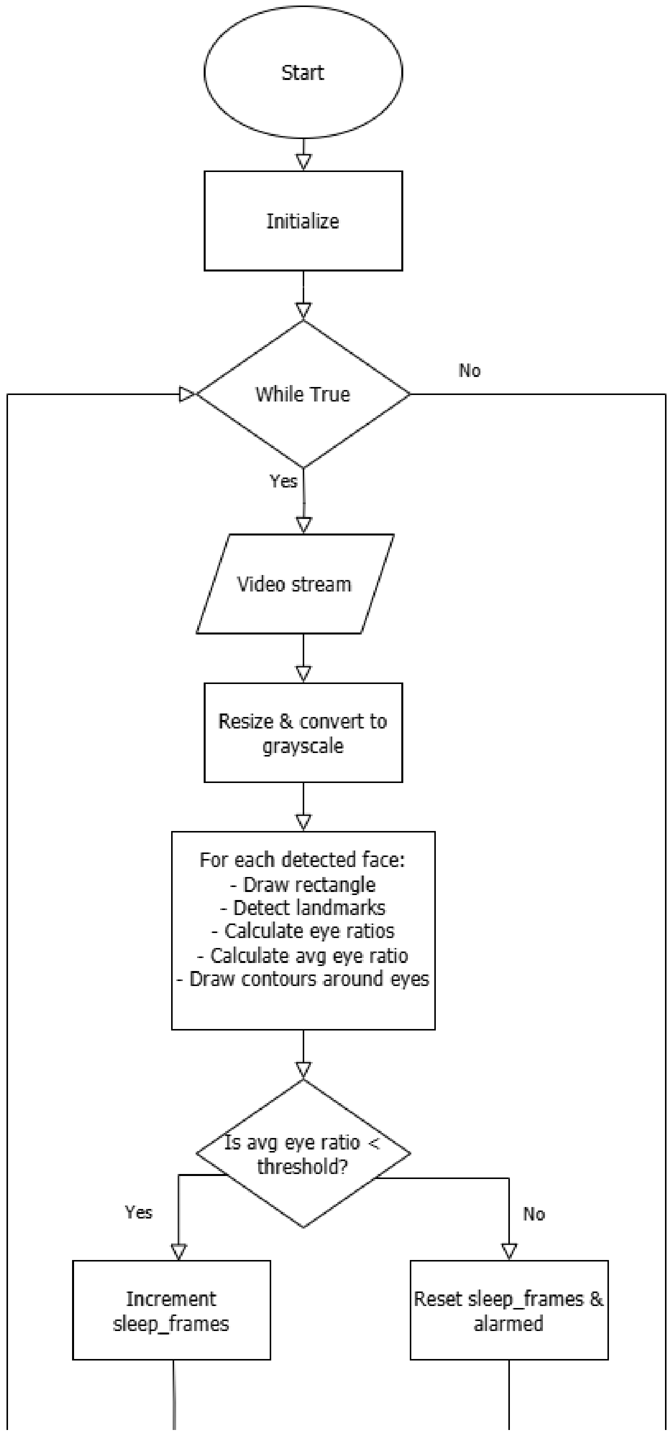


Figure 28: Visualizing the block diagram

b. Flow chart


Start
Initialize
While True
No
Yes
Video stream
Resize & convert to grayscale
For each detected face:
- Draw rectangle
- Detect landmarks
- Calculate eye ratios
- Calculate avg eye ratio
- Draw contours around eyes
Is avg eye ratio < threshold?
Yes
No
Increment sleep_frames
Reset sleep_frames & alarmed

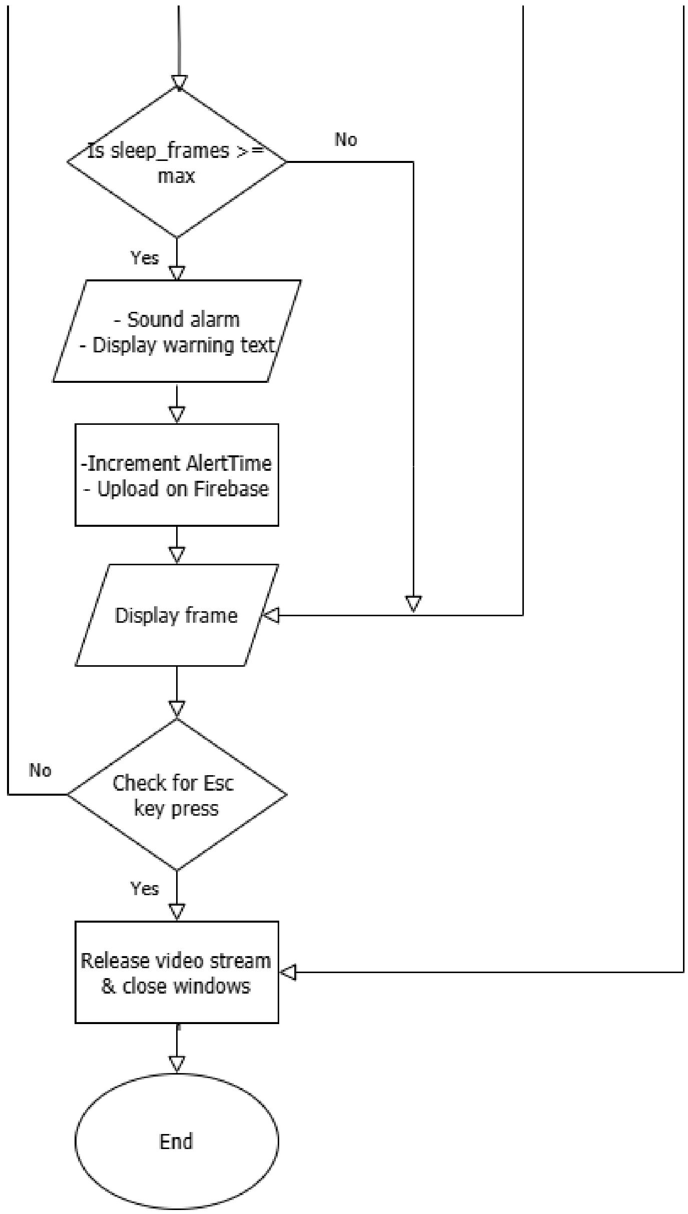


Figure 29: Flowchart of drowsiness recognition system

c. *Construction*

- Initially, face detection is performed using the Histogram of Oriented Gradients (HOG) detector in conjunction with a Support Vector Machine (SVM) classifier to determine the presence of a human face. Upon face detection, the Dlib library is employed to identify 68 facial landmarks using the Facial Landmark Detection function. These landmarks include eye and mouth positions

- Given the facial landmarks associated with an eye, we can apply the Eye Aspect Ratio (EAR) algorithm which was introduced by Soukupová and Čech’s in their 2017 paper

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

Figure 30: The eye aspect ratio (EAR) between height and width of the eye

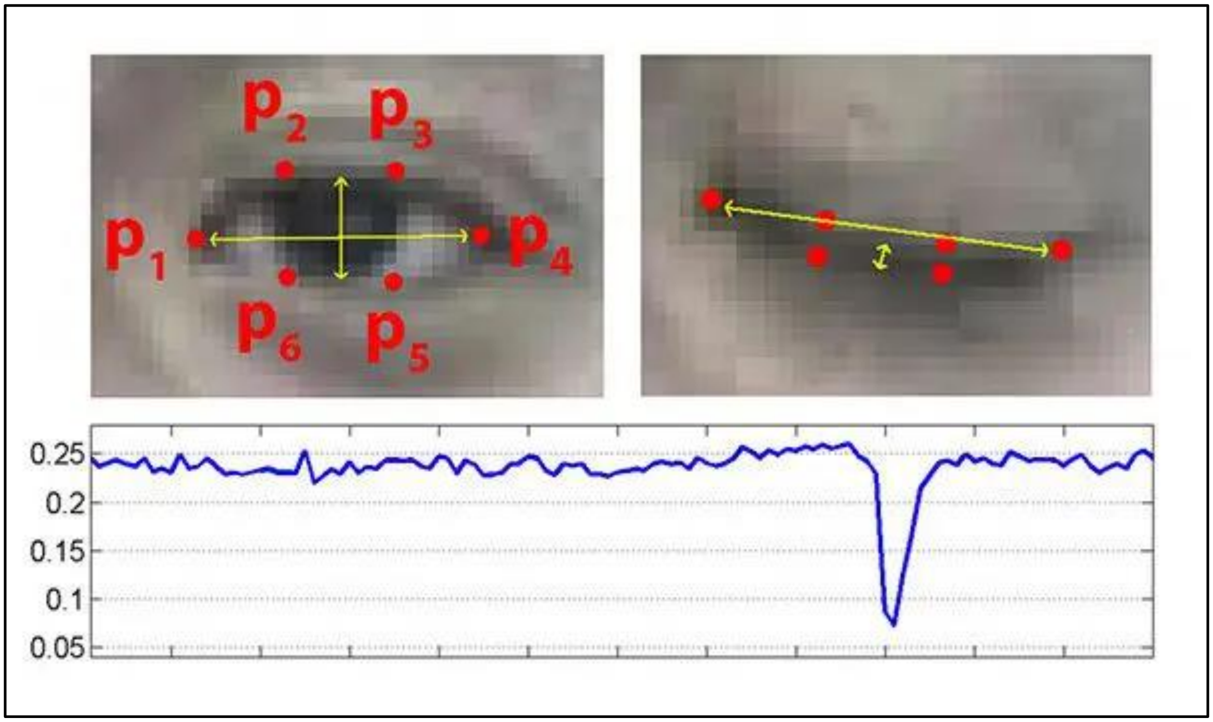


Figure 31: A visualization of eye landmarks when the eye is open, is closed. Plotting the eye aspect ratio over time

- In our drowsiness detector case, we’ll be monitoring the eye aspect ratio to see if the value falls but does not increase again, thus implying that the driver/user has closed their eyes.

- And then raising an alarm if the eye aspect ratio is below a predefined threshold for a sufficiently long amount of time.

- Finally, send the data to the phone app Thunkable through realtime database console in Firebase and set the time to message Whatsapp to the driver's family if needed

V. Stage Testing

1. Template

- To evaluate and comment most intuitively, the team conducted tests and detected drowsiness in different cases. Images of human faces in various states such as: straight or profile angle, closed or open eyes, wearing glasses or not, adequate or low light, and day or night, in a car or in a room, ...

Evaluation criteria		
OBJECTIVE EVALUATION	Accuracy	Detection accuracy for driver drowsiness (including both correct detection rate and false alarm rate).
		Ability to differentiate between drowsiness signs and other driver behaviors (eye rubbing, yawning, etc.).
		Performance under different lighting conditions (daytime, nighttime, low light).
		Image quality
	Reliability	Stable and continuous operation for extended periods.
		Resistance to interference from surrounding environment (noise, vibrations, etc.).
		Tolerance for harsh weather conditions (high temperature, high humidity, etc.).
	Ease of Use	Simple and intuitive user interface.
		Straightforward installation and operation process.
		Clear and comprehensive user manual.
	Functionality	Drowsiness alert features (sound, vibration, etc.).
		Connectivity with other devices (smartphone, GPS, etc.).
	Cost	
	Size and design	
Evaluation criteria Rating		
SUBJECTIVE EVALUATION	Ease of Use	Simple and intuitive user interface.
		Straightforward installation and operation process.
		Clear and comprehensive user manual.
	Functionality	Drowsiness alert features (sound, vibration, etc.).
		Connectivity with other devices (smartphone, GPS, etc.).
	Cost	
	Size and design	
	Convenience	

Table 10: Evaluation criteria

Evaluation Scenario	
Lab Testing	Use pre-recorded videos showcasing driver behavior in various states (drowsy, alert, etc.).
	Run the Raspberry Pi drowsiness detection system and record results.
	Compare results with human evaluation for accuracy determination.
Real - World Testing	Install the Raspberry Pi system in several vehicles.
	Have drivers operate vehicles under different conditions (highway, city streets, etc.).
	Log system performance and gather driver feedback.
	Analyze collected data to assess real-world effectiveness.
Evaluation Participants	
Drivers	

Table 11: Evaluation scenario and evaluation participants

2. *Result*

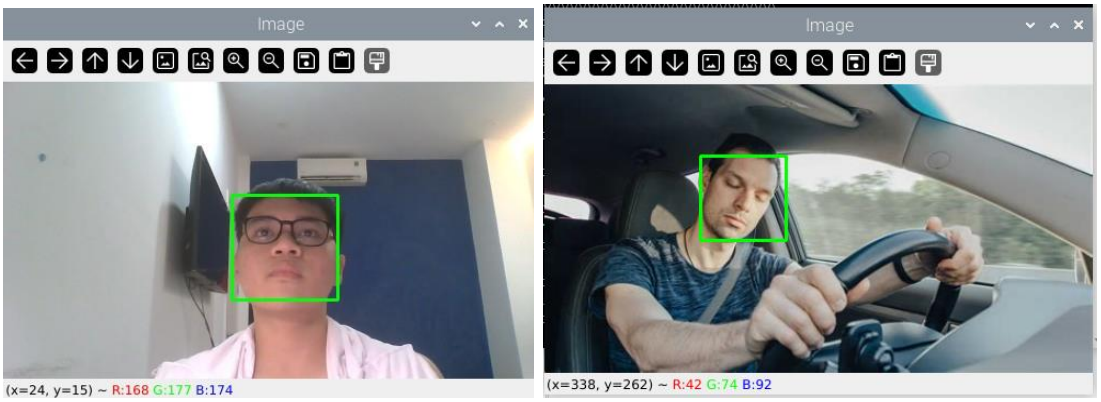


Figure 32: Identification in case of opening and closing eyes

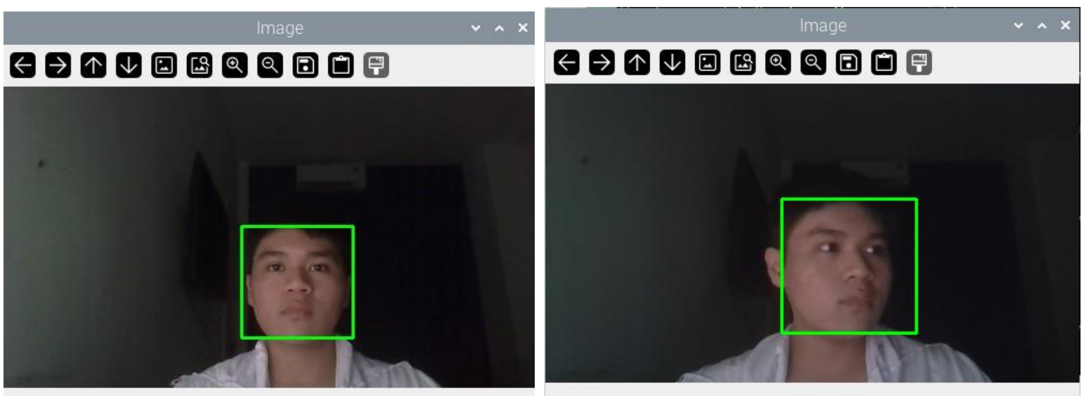


Figure 33: Identification in case of opening or closing eyes without glasses

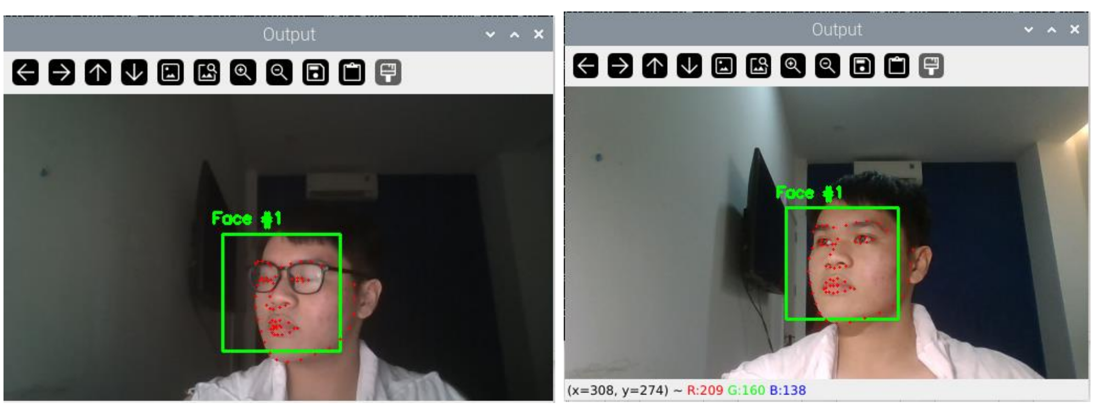


Figure 34: Identification of 68-point facial landmarks

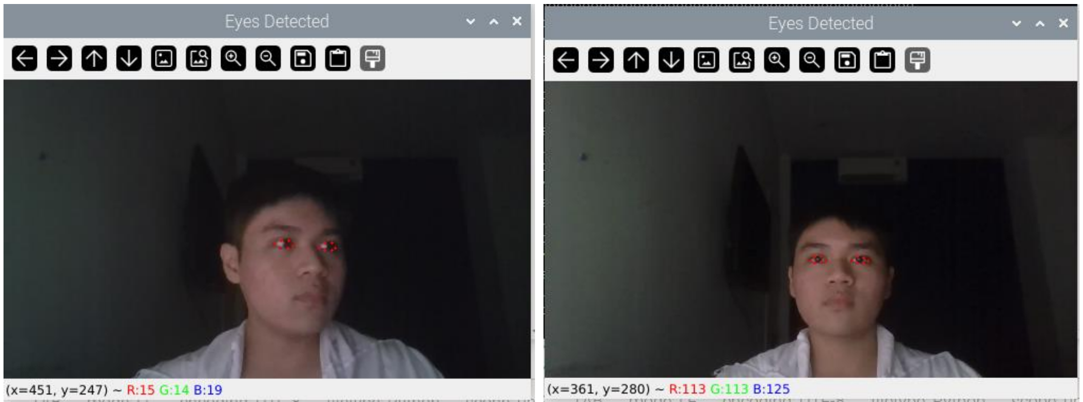


Figure 35: Identification of facial eyes landmarks

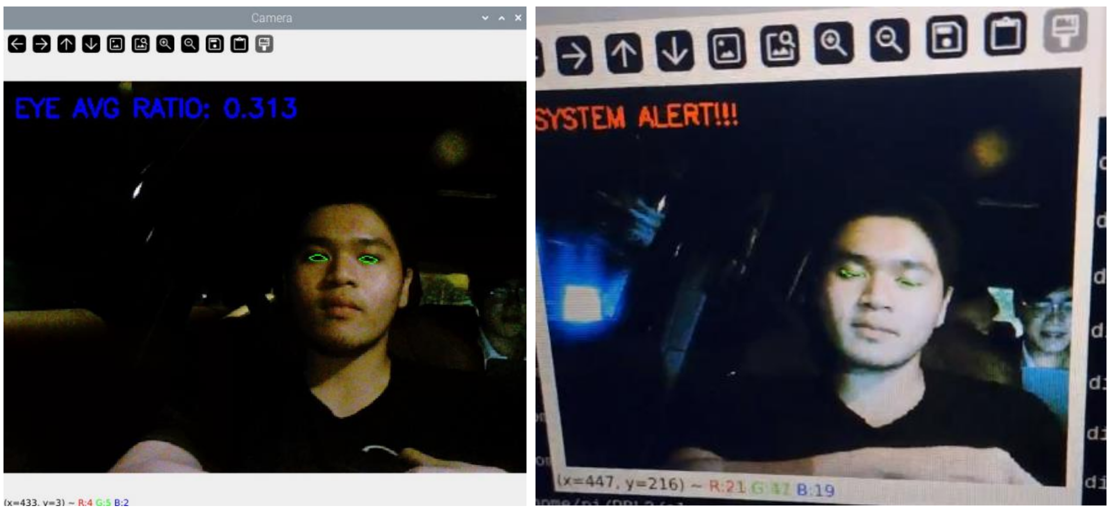


Figure 36: Recognition in case of opening and closing eyes at night in the car.

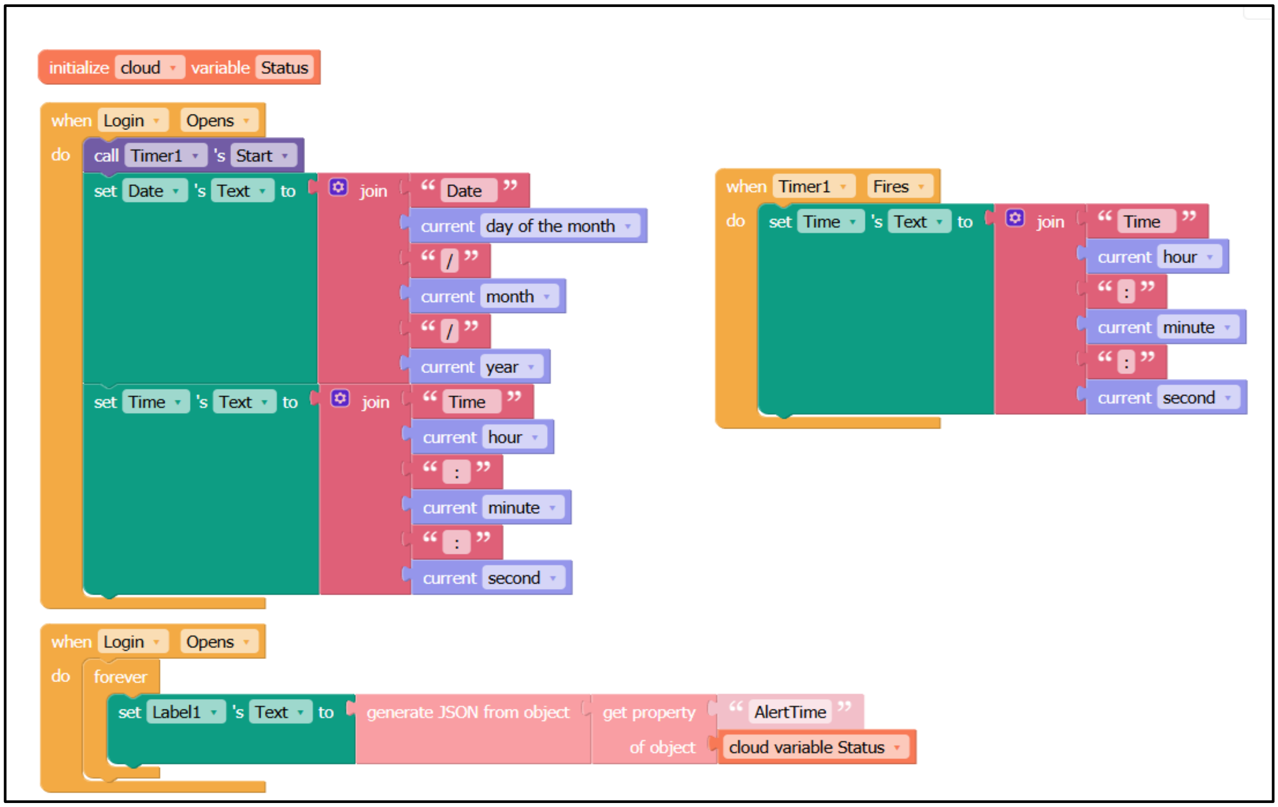


Figure 37: Block diagram on Thunkable view

Figure 38: Realtime database console on Firebase view

Figure 39: Thunkable application view

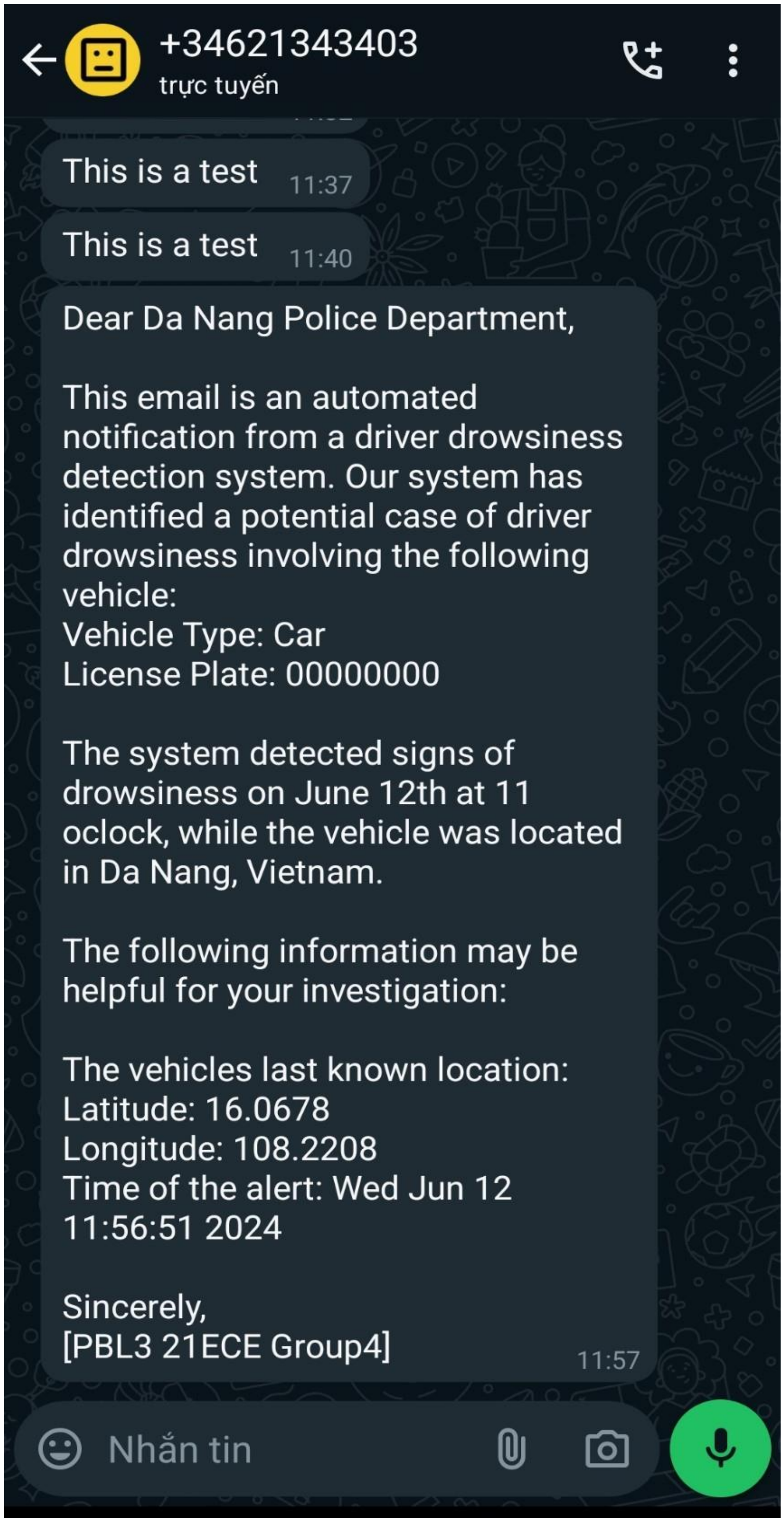


Figure 40: CallMeBot API message alert

Table 12: Results of eye state recognition with straight and tilted angles in the room (in class).

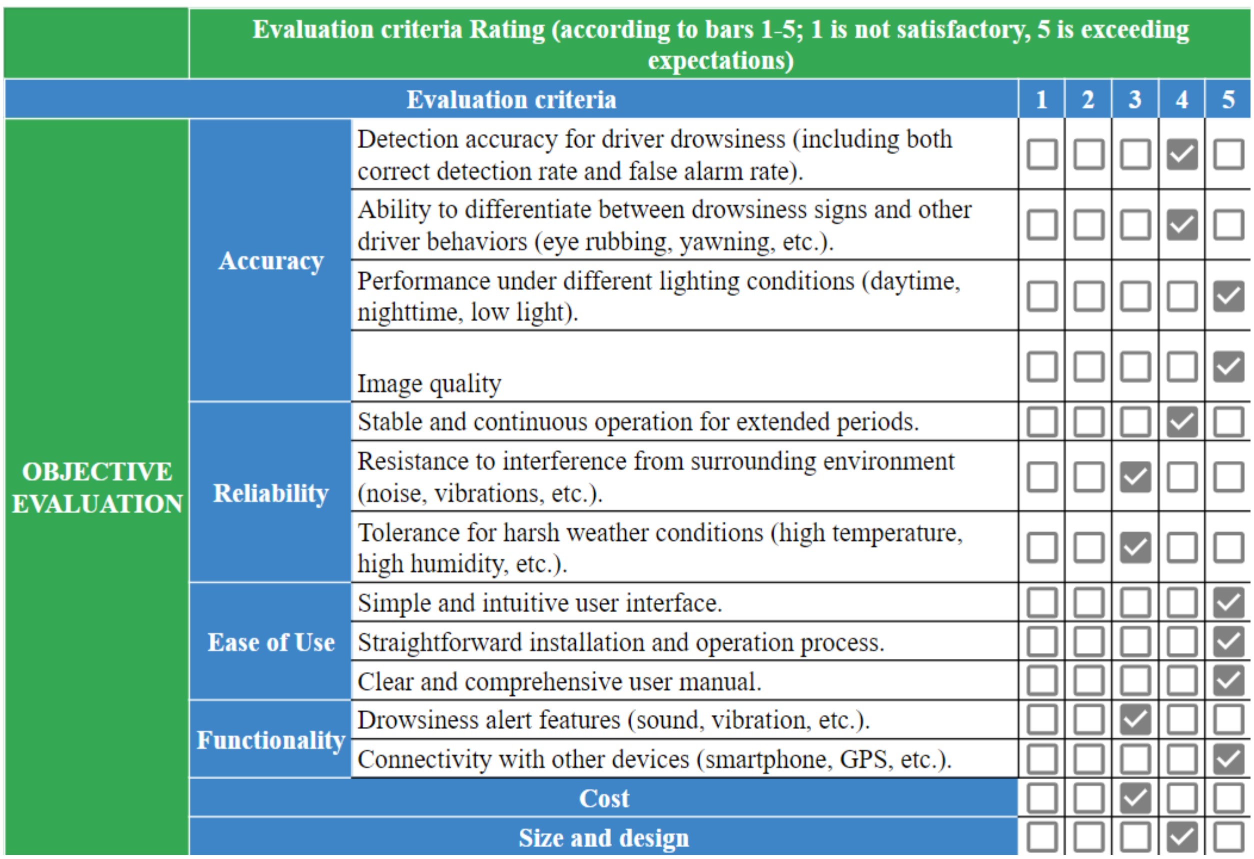
	Straightedge			
	Bright enough		Lack of light	
	There are glasses	No glass	There are glasses	No glass
Aim	45/50 = 90%	47/50=94%	35/50 = 70%	38/50 = 76%
Open	46/50 = 92%	48/50=96%	37/50 = 74%	40/50 = 80%
	Tilt angle			
	Bright enough		Lack of light	
	There are glasses	No glass	There are glasses	No glass
Aim	42/50 = 84%	44/50 = 88%	30/50 = 60%	35/50 = 70%
Open	45/50 = 90%	46/50 = 92%	33/50 = 66%	37/50 = 74%

Table 13: Results of eye state recognition with straight and tilted angles in the vehicle (daytime).

	Straightedge			
	Bright enough		Lack of light	
	There are glasses	No glass	There are glasses	No glass
Aim	40/50 = 80%	43/50 = 86%	31/50 = 62%	33/50 = 66%
Open	42/40 = 84%	44/50 = 88%	34/50 = 68%	37/50 = 74%
	Tilt angle			
	Bright enough		Lack of light	
	There are glasses	No glass	There are glasses	No glass
Aim	38/50 = 78%	41/50 = 82%	33/50 = 66%	34/50 = 68%
Open	40/50 = 80%	43/50 = 86%	35/50 = 70%	38/50 = 78%

Table 14: Results of eye state recognition with straight and tilted angles in the vehicle (at night).

	Straightedge			
	Bright enough		Lack of light	
	There are glasses	No glass	There are glasses	No glass
Aim	39/50 = 78%	40/50 = 80%	30/50 = 60%	31/50 = 63%
Open	40/50 = 80%	42/50 = 84%	35/50 = 70%	37/50 = 74%
	Tilt angle			
	Bright enough		Lack of light	
	There are glasses	No glass	There are glasses	No glass
Aim	37/50 = 74%	40/50 = 80%	30/50 = 60%	31/50 = 63%
Open	39/50 = 78%	42/50 = 84%	31/50 = 63%	33/50 = 66%

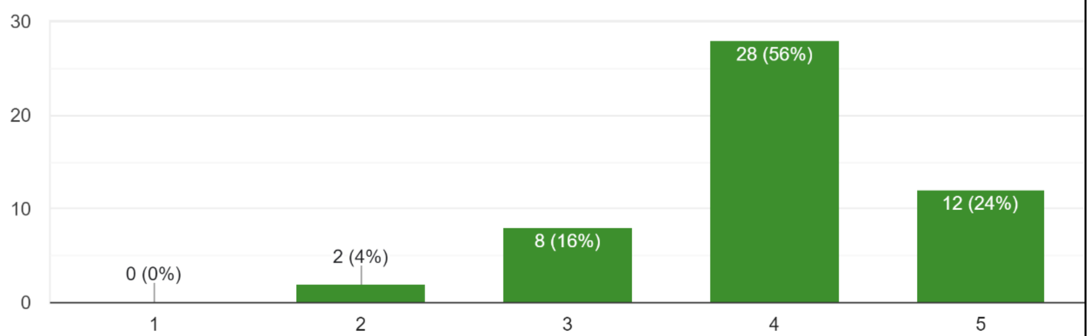


	Evaluation criteria Rating (according to bars 1-5; 1 is not satisfactory, 5 is exceeding expectations)						
Evaluation criteria			1	2	3	4	5
OBJECTIVE EVALUATION	Accuracy	Detection accuracy for driver drowsiness (including both correct detection rate and false alarm rate).				✓	
		Ability to differentiate between drowsiness signs and other driver behaviors (eye rubbing, yawning, etc.).				✓	
		Performance under different lighting conditions (daytime, nighttime, low light).					✓
		Image quality					✓
	Reliability	Stable and continuous operation for extended periods.				✓	
		Resistance to interference from surrounding environment (noise, vibrations, etc.).			✓		
		Tolerance for harsh weather conditions (high temperature, high humidity, etc.).			✓		
	Ease of Use	Simple and intuitive user interface.					✓
		Straightforward installation and operation process.					✓
		Clear and comprehensive user manual.					✓
	Functionality	Drowsiness alert features (sound, vibration, etc.).			✓		
		Connectivity with other devices (smartphone, GPS, etc.).					✓
	Cost				✓		
	Size and design					✓	

Figure 41: Obejective evaluation

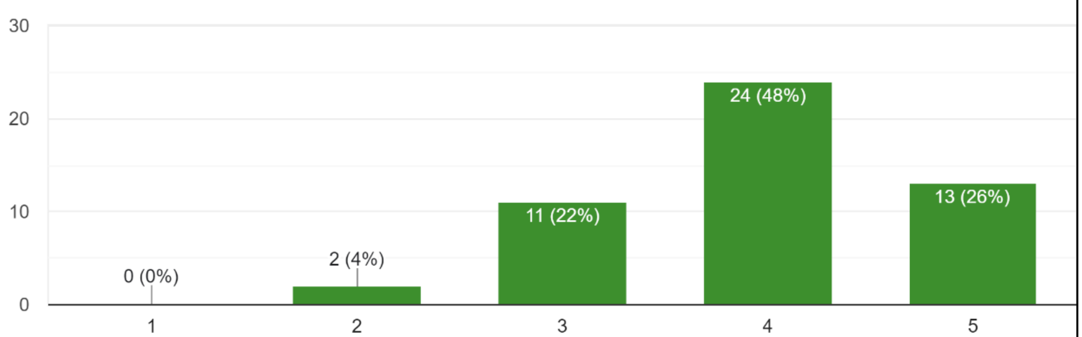
Do you feel the User Interface is simple and intuitive? Strongly Disagree: 1 Disagree: 2 Neutral: 3 Agree: 4 Strongly Agree: 5

50 câu trả lời



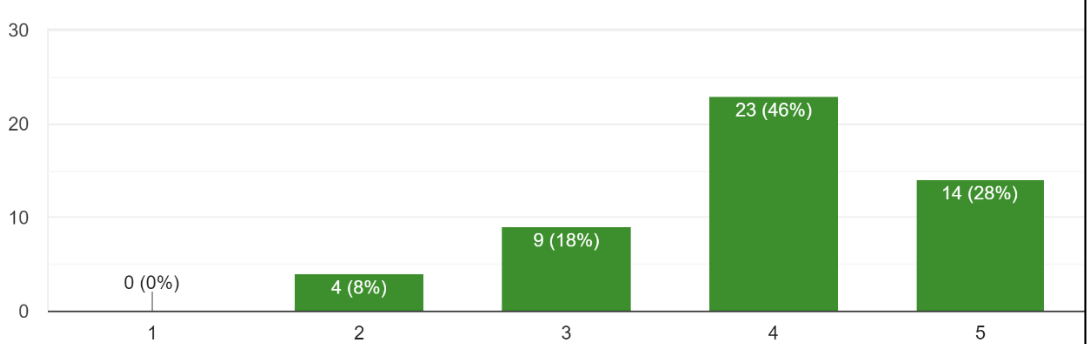
Do you feel the installation and operation process is straightforward? Strongly Disagree: 1 Disagree: 2 Neutral: 3 Agree: 4 Strongly Agree: 5

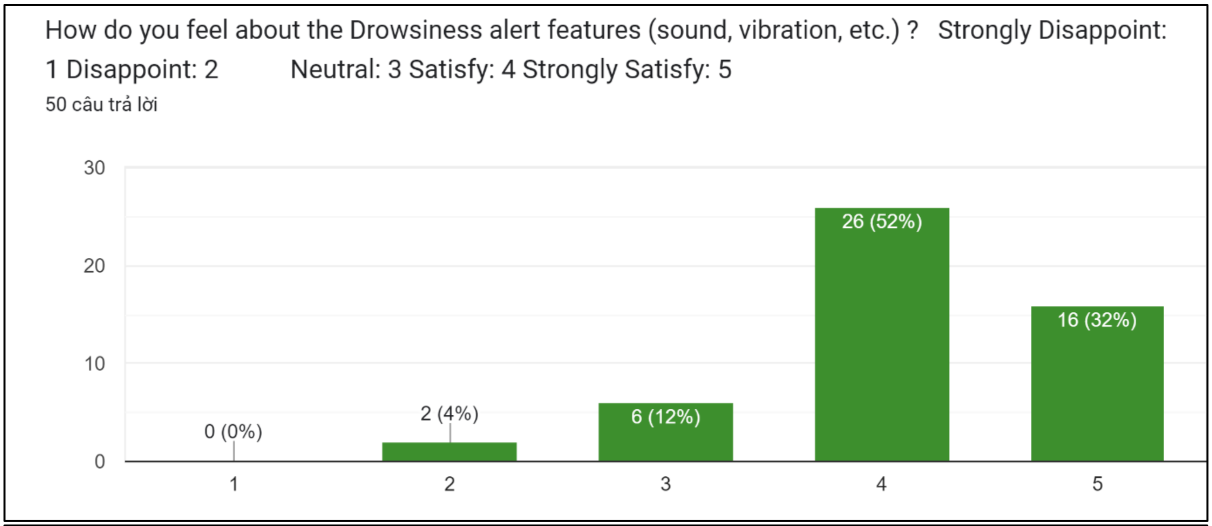
50 câu trả lời

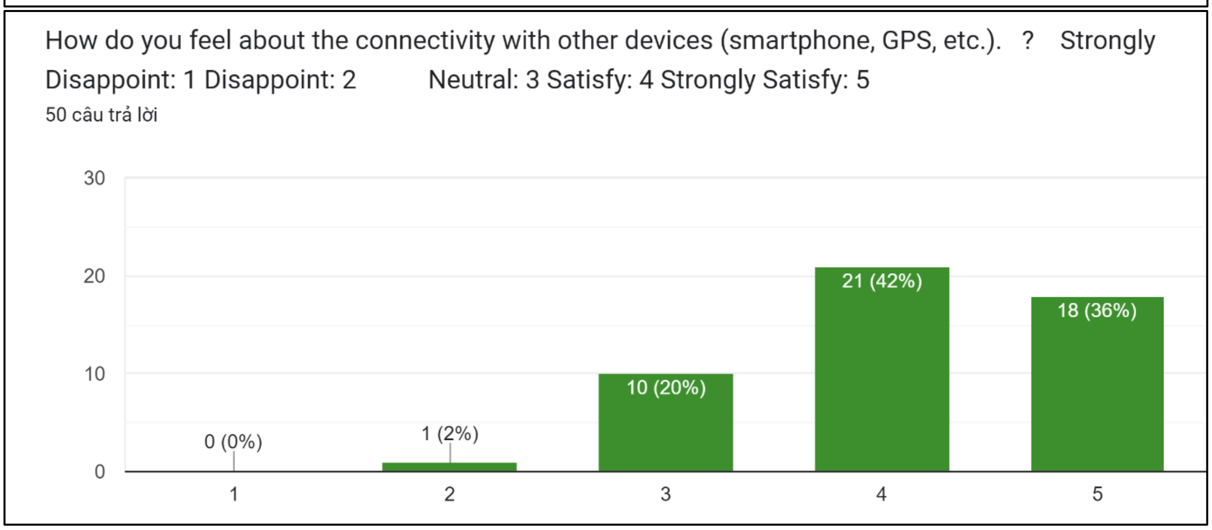


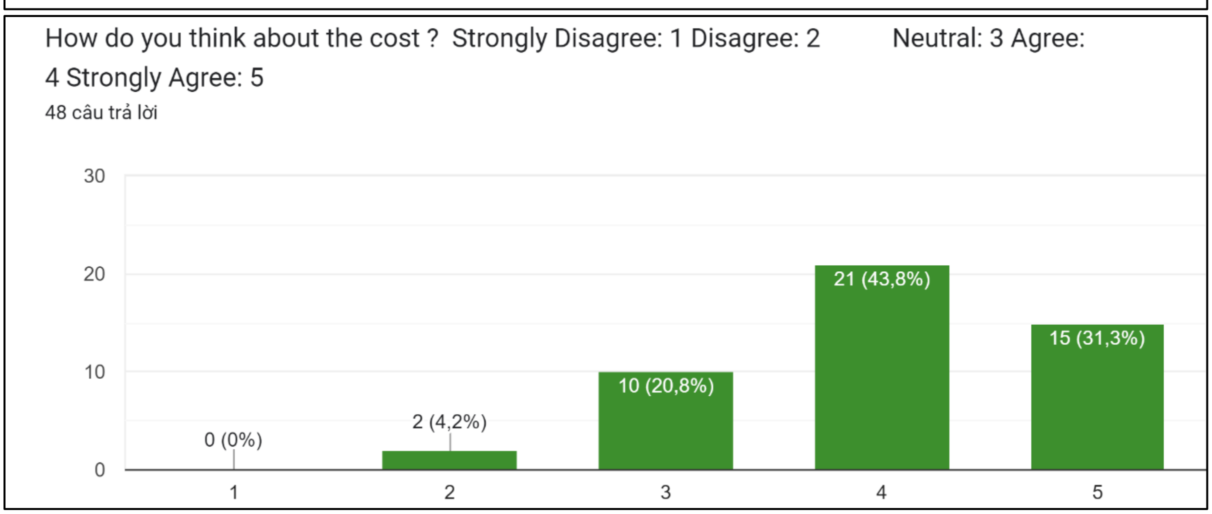
Do you feel the user manual is clear and comprehensive? Strongly Disagree: 1 Disagree: 2 Neutral: 3 Agree: 4 Strongly Agree: 5

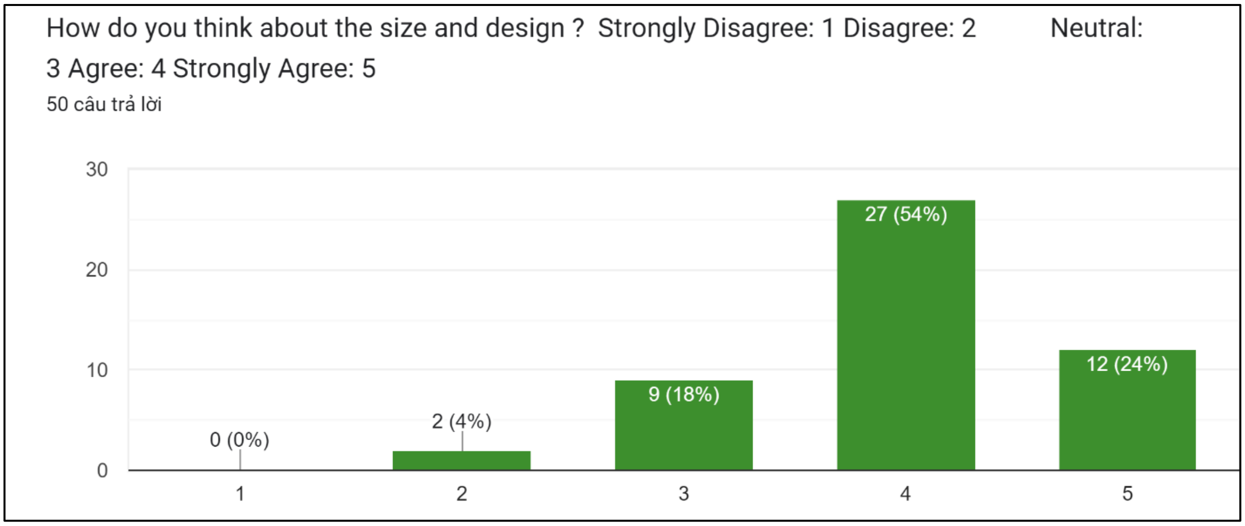
50 câu trả lời




How do you feel about the Drowsiness alert features (sound, vibration, etc.) ? Strongly Disappoint: 1 Disappoint: 2 Neutral: 3 Satisfy: 4 Strongly Satisfy: 5
50 câu trả lời
0 (0%)
2 (4%)
6 (12%)
26 (52%)
16 (32%)


How do you feel about the connectivity with other devices (smartphone, GPS, etc.). ? Strongly Disappoint: 1 Disappoint: 2 Neutral: 3 Satisfy: 4 Strongly Satisfy: 5
50 câu trả lời
0 (0%)
1 (2%)
10 (20%)
21 (42%)
18 (36%)


How do you think about the cost ? Strongly Disagree: 1 Disagree: 2 Neutral: 3 Agree: 4 Strongly Agree: 5
48 câu trả lời
0 (0%)
2 (4,2%)
10 (20,8%)
21 (43,8%)
15 (31,3%)



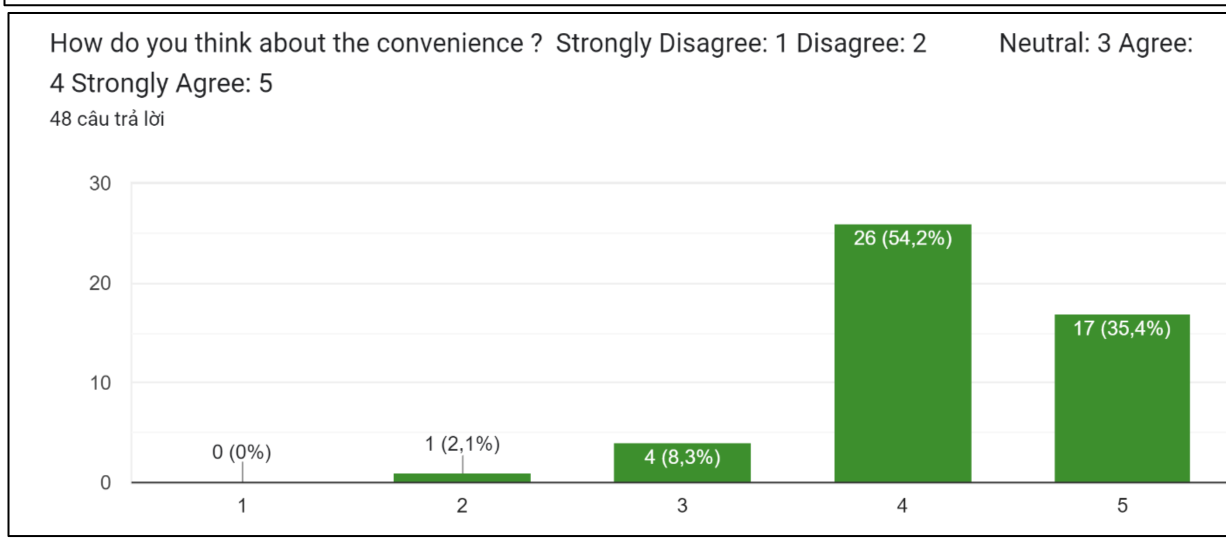


Figure 42: Subjective evaluation

3. *Comment*

- The results show that the accuracy is quite high in both lab and actual detection on cars under different conditions. However, in the case of lack of light in the lab and lack of light (streetlights) in the car at night, the accuracy is lower. And face recognition must be frontal and the lights in the car turned on so there is light to be able to recognize faces.
- As for wearing glasses, it does not have too much impact on identifying and calculating indicators. However, like the above comment, difficult detection or inaccurate detection relies more on facial lighting, so it is easier to solve when the

interior lights are on. For sunglasses and sunglasses, the eyes will not be detected, so detecting drowsiness is impossible.

4. *Future work*

- Enhance the system's robustness to variations in lighting and image quality.
- Developing a user-friendly interface for configuring and calibrating the system would enhance user experience and adoption.
- Developing a tracking data system

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[10] Paul Viola and Michael Jones, Rapid Object Detection using a Boosted Cascade of Simple Features, 2001.

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[12] Dalal and Triggs in their seminal 2005 paper, Histogram of Oriented Gradients for Human Detection.

[13] Tereza Soukupova and Jan Cech, Real-Time Eye Blink Detection using Facial Landmarks, 2016