1. PROBLEM STATEMENT

Driver fatigue is a leading cause of vehicular accidents, resulting in many fatigue-related crashes being left unreported due to the difficulties in recognizing fatigue as an essential contributor. Awake-Pilot is designed to overcome this problem by improving driver awareness and implementing accident prevention measures. By observing a driver's behavior and alerting the driver when fatigue is detected, Awake-Pilot aims to reduce the associated risks a driver may experience when fatigued.

1.1 Need Statement

According to the Centers for Disease Control and Prevention, approximately 1 in 25 adult drivers admit to having fallen asleep behind the wheel, while a survey found that 1 in 3 adults responded to driving despite being sleep-deprived [1]. In 2022, reports indicated that over 1,261 drowsy drivers were involved in fatal crashes, accounting for approximately 2.1% of all deadly vehicular accidents [2]. Studies reveal that lack of sleep impairs cognitive function similarly to alcohol intoxication, with 24 hours of sleep deprivation being comparable to a blood alcohol concentration (BAC) of 0.1% [3]. Drowsy driving is an extremely dangerous problem. A solution is needed to detect and alert drivers of drowsiness and ensure road safety.

1.2 Objective Statement

The objective of Awake-Pilot is to monitor the driver's behavior for drowsiness and send a responsive alert whenever fatigue is detected in the driver to ensure safer driving. The device utilizes RGB and an HD infrared camera to track the driver's eye and facial movements to detect hazardous drowsiness. Awake-Pilot uses a dual alert system with high-pitched noise and seat-installed vibration alerts to reawaken the user. The device is designed to be installed on the dashboard of the vehicle and powered through the car's auxiliary port to automatically turn on once the user starts the vehicle and remains operational until the vehicle is turned off.

1.3 Background and Related Work

Fatigue detection devices ranging from the 1990s to 2000s primarily rely on physiological signals such as the percentage of eyelid closure over the pupil over time (PERCLOS), while more modern approaches, emerging in the late 2000s, use computer vision with RGB and infrared (IR) cameras to detect signs of drowsiness through other bodily movements, such as prolonged eye closure, yawning, and head nodding [4]. Current fatigue detection devices utilize a single-modal system; however, single-modal systems that only use RGB or IR cameras have limitations—RGB struggles in low light, while IR excels in low-light conditions but lacks detailed color quality. The multimodal system of the Awake-Pilot compensates in the areas where both cameras fall short by allowing for both cameras to be utilized at once, ensuring reliable detection across varying lighting conditions. Patented technologies support a multimodal approach. US Patent US20210241011A1 details facial landmark analysis with image sensors and neural networks, while EP1418082A1 focuses on eye closure measurement via video processing. These highlight the value of multimodal imaging for accuracy [5]. By combining RGB and IR imaging, Awake-Pilot offers a robust, real-time driver monitoring solution, enhancing road safety by reducing drowsiness-related risks.

2. DESIGN REQUIREMENT SPECIFICATIONS

This section provides an overview of the design requirements that have been considered in the design, prototyping, and implementation in the development of the Awake-Pilot.

2.1 Requirements

Aiming to improve road safety, the Awake-Pilot's AI detection system recognizes a driver's drowsiness and triggers an instant alert to help prevent fatigue-related crashes. The following sections demonstrate how the device meets user expectations and engineering requirements while guaranteeing overall safety and functionality. Both the radar and image processing subsystems function independently, while the alert subsystem depends on the proper functionality of the others in order to make Awake-Pilot possible.

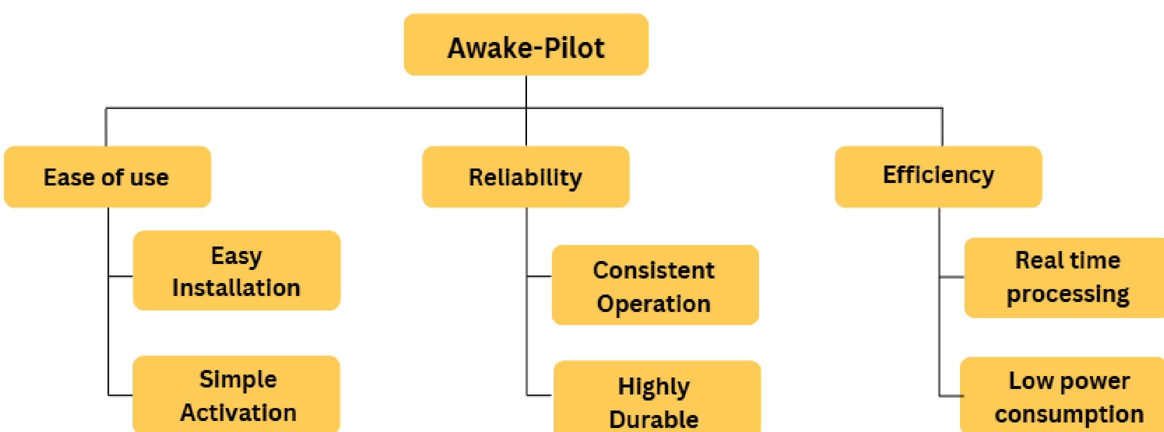
2.1.1 Marketing Requirements

The Awake-Pilot's marketing requirements are outlined as follows:

1. The device constantly tracks eyelid movements to ensure the driver is awake.
2. The device continues to monitor eyelid closure in low-light environments, guaranteeing proper functionality in dark settings.
3. The device's vibrations and sounds will awaken even the deepest sleepers.
4. The device is easy to use and install.

Figure 2-1 displays the Awake-Pilot's objective tree outlining the market requirements.

Figure 2-1: Objective Tree for Awake-Pilot



The objective tree provides an outline for the Awake-Pilot's goal and plans to make the product operate successfully.

2.1.2. Engineering Requirements

Table 2-1 presents the engineering requirements that must be met to satisfy the marketing requirements detailed in Section 2.1.1.

Table 2-1: Engineering Design Requirements

Marketing Requirements	Engineering Requirements	Description
1	Image processing tracks eyelid movement at 30 fps and 640×480 resolution.	Ensures continuous eyelid tracking, detecting subtle changes for drowsiness detection.
1	The microcontroller processes drowsiness detection in 150 milliseconds.	Real-time data processing triggers an immediate alert when drowsiness is detected.
2	The system uses both imaging processing and sensor data to monitor the eyelids precisely.	Combines systems for reliable eyelid detection in varying light conditions.
2	Eye Closure is accurately detected under all lighting conditions, including total darkness.	Enables eyelid detection in complete darkness for reliable nighttime operation.
2	The system is designed with high sensitivity for precise eyelid detection.	Guarantees accuracy in dim environments and complete darkness.
3	The alert system produces 80 dBA sound at 1 m.	Ensures sound intensity is sufficient to wake even the deepest sleepers.
3	The alert system generates a 2G vibration at a 250 Hz frequency.	Provides vibration strong enough to rouse deep sleepers.
4	Easily plugs into a car's auxiliary port for automatic sensor calibration.	Simplifies installation and minimizes user intervention.
4	Unified communication interface enables setup in 15 minutes.	Quick and easy setup without technical expertise required.

Marketing Requirements:

1. The device constantly tracks eyelid movements to ensure the driver is awake.

2. The device continues to monitor eyelid closure in low-light environments, guaranteeing proper functionality in dark settings.

3. The device's vibrations and sounds will awaken even the deepest sleepers.

4. The device is easy to use and install.

The system utilizes a high-speed camera module that captures video at 30 frames per second (fps) with a resolution of 640×480 pixels, the minimum requirements necessary for effective image processing. This ensures reliable eyelid detection is maintained through efficient processing speed. The high-performance processing unit runs an optimized convolutional neural network (CNN) for real-time eyelid monitoring, allowing for the system to distinguish between open and closed eyelids with over 90% accuracy in empirical testing. To avoid misinterpreting normal blinking, the system sets a half-second limit for eyelid closures, ensuring only drowsiness-related triggers are detected. With a processing delay of about 50 milliseconds per frame allowing for even the briefest eyelid closures, for example microsleeps, are accurately detected, making real-time tracking of drowsiness possible.

To ensure eyelid closure can be detected in complete darkness, the system integrates a highly sensitive sensor designed to capture high-quality images to be processed even in the lowest of light conditions. This ensures the device accurately detects eyelid movements even when there is no visible light. To maintain optimal image quality, an automatic gain control (AGC) algorithm adapts the sensor’s sensitivity in real-time, enhancing the precision of detecting eyelid movements. This adaptive approach ensures that even subtle eyelid closures are reliably detected, making the system effective in a wide range of lighting conditions.

The alert system incorporates two systems of detection of drowsiness: auditory and vibrational. A piezoelectric buzzer is calibrated to produce an audio signal of at least 80 dBA measured 1 meter away. Additionally, a vibrating motor is designed to generate vibrations with a minimum acceleration of 2G at a frequency of approximately 250 Hz. These specifications ensure the device's stimuli are sufficient enough to rouse even the deep sleepers, based on human factors research that support these thresholds for effective arousal response [6].

The device is designed to be powered by a car auxiliary port, which simplifies installation and setup and allows for automated sensor calibration. This allows for an automated calibration routine to be executed upon startup, initializing all sensor parameters and completing the process in under 15 minutes. This ensures the device can be operational with minimal user intervention, promoting ease of use and reducing setup complexity.

The system combines collected data from multiple sensors, including a camera and radar, to detect drowsiness in the driver. The data is quickly processed allowing for a response time of under 150 milliseconds from when the data is collected. The fast processing is essential for providing immediate alert responses to the driver, ensuring a warning is given to help enhance driver safety during events of potential drowsiness.

2.2 Constraints

Awake-Pilot faces a variety of constraints in the development of the device. This includes voltage limits, camera accuracy, and compatibility, as listed in Table 2-2.

Table 2-2: Constraints

Type	Name	Description
Economic	Time	The team faces the challenge of having to complete Awake-Pilot in two semesters.
Economic	Cost	The total budget of the project is $1000.

Functionality	Compatibility	Each subsystem and their voltage limits will have to be compatible with each other.
Energy	Power Source	The average car battery outputs a limit of 12–15 volts.
Health and Safety	Safety	The alert subsystem's noise metrics must be set below 90 decibels.
Reliability	Accuracy	The camera relies on eye closure and head motion for detection.

Awake-Pilot faces economic constraints with a limited budget of $1000. Meaning the components needed to develop the device must stay within the allocated budget. The time duration also poses a constraint with only a two-semester development window to design, prototype, and develop the device.

The functionality constraint of Awake-Pilot is caused by compatibility between each subsystem. Each subsystem could rely on a different port, such as USB types, which could cause connection issues and issues with voltage regulation. The average car battery outputs 12-15 V depending on the state of the alternator. Due to this constraint, the chosen overall voltage limit of all components is 3-5 V in order to prevent damage.

The safety constraint of Awake-Pilot derives from the alert subsystem's alarm. According to the Hear-ing Health Foundation, the alarm cannot be higher than 90 decibels or it can cause permanent hear-ing damage. [7]. Which may cause an issue with the reliability. The constraint of reliability of the device derives from the camera's limited detection of eye tracking and head motion. As a result of this accuracy constraint, Awake-Pilot could face false positives from blinking and temporarily leaning back.

2.3 Standards

Table 2-3 lists the six standards to which Awake-Pilot adheres to, ensuring that the device's hardware and software are safe, interoperable, and functional under industry standards and protocols.

Table 2-3: Engineering- Standards

Specific Standard	Standard Document	Specification / Application
ISO 16750-2	The International Organization for Standardization (ISO) 16750-part 2 standard for electric loads in vehicles [8].	Awake-Pilot relies on the power given by a vehicle's auxiliary port and must function when, temporarily, the voltage drops below 6V.
IEEE 1857	The Institute of Electrical and Electronics Engineers (IEEE) standard for video coding standards [9].	Awake-Pilot uses facial recognition and imaging processing, which requires near-instantaneous processing of frames by the microcontroller.

ISO 26262	The International Organization for Standardization (ISO) 26262 standard for safety functionality for motorized vehicles [10].	Awake-Pilot incorporates a priority alert system through sounds and vibrations to alert the driver of fatigue and ensure proper functionality.
ISO 13407	The International Organization for Standardization (ISO) 13407 standard for safety functionality for motorized vehicles [11].	Awake-Pilot adapts to the driver's behavior to ensure the activation of the alert system happens at proper detection of fatigue to avoid false positives.
ISO/IEC 25010	The International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC) 25010 standard for quality software are being utilized [12].	Awake-Pilot utilizes an AI driver fatigue monitoring system that uses optimal performance to avoid any lag or delay in facial recognition.
ISO 16750	The International Organization for Standardization (ISO) 16750 standard ensures automotive devices are protected against real-world conditions [13].	Awake-Pilot is a dash-mounted device that ensures that the device is securely mounted to avoid any issues that may arise due to vibration.

By adhering to industry and safety standards, Awake-Pilot monitors the driver for fatigue while ensuring optimal software, electrical current/voltage, and mounting are within the engineering standards for the device.

2.4 References

[1] S. Larky, et al, “You’ve come a long way, USB: history and future of USB port technology,” Electronic News, July 2001. [Online]. Available: http://findarticles.com/p/articles/mi_m0EKF/is_30_47/ai_76780475. [Accessed: Sept 7, 2007].

[2] J. M. D. Pereira, “The history and technology of oscilloscopes: an overview of its primary characteristics and working principles,” IEEE Instrumentation and Measurement Magazine, pp. 27-35, December 2006. [Online]. Available: http://ieeexplore.ieee.org. [Accessed: Sept. 4, 2007].

[3] Bagley College of Engineering, “Computer Requirements Overview,” Bagley College of Engineering, 2007. [Online]. Available: http://www.engr.msstate.edu/prospective_students/computer_initiative. [Accessed: Sept. 5, 2007].

[4] M. T. Gibbons, “Engineering by the Numbers,” American Society for Engineering Education, 2007. [Online]. Available: http://www.asee.org/publications/profiles/upload/2006ProfileEng.pdf. [Accessed: Sept. 4, 2007].

[5] Tektronix, “Tektronix Company Overview: Markets, Strategy, and Results,” Tektronix Inc., May 2007. [Online]. Available: http://library.corporateir.net/library/81/815/81500/items/244554/Company_Presentation_2007_v3.pdf. [Accessed: Sept. 5, 2007].

[6] M. Ramzan, H. U. Khan, S. M. Awan, A. Ismail, M. Ilyas, and A. Mahmood, “A Survey on State-of-the-Art Drowsiness Detection Techniques,” IEEE Access, vol. 7, no. 1, pp. 61904–61919, 2019, doi: https://doi.org/10.1109/access.2019.2914373.

[7] Hearing Health Foundation, “Keep Listening: Decibels,” Hearing Health Foundation, Mar. 2025. [Online]. Available: https://hearinghealthfoundation.org/keeplistening/decibels

[8] ISO - International Organization for Standardization, “ISO 16750-2:2023,” ISO, 2023. https://www.iso.org/standard/76119.html

[9] IEEE - Institute of Electrical and Electronics Engineers, “IEEE Standards Association,” IEEE Standards Association, 2023. https://standards.ieee.org/ieee/1857/10644/

[10] ISO - International Organization for Standardization, “ISO 26262-1:2011,” ISO, 2011. https://www.iso.org/standard/43464.html

[11] ISO - International Organization for Standardization, “ISO 13407:1999,” ISO, 2010. https://www.iso.org/standard/21197.html

[12] ISO - International Organization for Standardization, “ISO/IEC 25010:2011,” ISO, 2011. https://www.iso.org/standard/35733.html

[13] ISO - International Organization for Standardization, “ISO 16750-1:2023,” ISO, 2023. https://www.iso.org/standard/77578.html

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