AngelRide: An Autonomous Smart Car Seat for Continuous Child Safety with IoMT

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***Abstract*—Driver distraction is a major contributor to road accidents, and the presence of children, whether crying or unusually quiet, often increases that distraction. AngelRide, an Internet of Medical Things (IoMT) system, addresses this problem by automatically monitoring a child's condition in the car seat and easing the driver's cognitive load. The device uses an advanced computer-vision pipeline: a YOLOv11 model first detects a seated child, then an eye-tracking module classifies their sleep state. A suite of environmental sensors continually adjusts light, temperature, humidity, and sound to maintain optimal sleeping conditions. By improving the child's comfort and minimizing driver concern, AngelRide simultaneously enhances in-vehicle safety and the child's sleep quality.**

***Index Terms*—component, formatting, style, styling, insert**

I. INTRODUCTION

In 2023, distracted driving resulted in the deaths of over 3,000 people in the United States [1]. Driving requires full attention to ensure the safety of both passengers and other road users. An estimated 94% of car crashes are caused by driver error or inattention, making roads significantly less safe [2]. Even a moment of inattention can lead to fatal or serious injuries. Therefore, drivers should avoid any potential distractions, such as using smartphones or driving under the influence of alcohol [3].

Passengers play an important role in helping the driver stay focused on the road. However, infant passengers can unintentionally divert the driver's attention. To reduce this risk, children should always be secured in a car seat. A proper car seat not only protects the child in case of an accident but also allows the driver to concentrate better. Nevertheless, even when a child is safely seated, the driver may still feel the need to monitor the child's condition. In some cases, the driver may need to stop the vehicle to check on the child's health [4].

Most of the time, children fall asleep in their car seats, which allows the driver to remain focused, knowing the child is safe. However, for the child to sleep comfortably, certain environmental conditions must be maintained. Factors such as temperature, sunlight, and ambient noise can significantly affect sleep quality. The objective of the proposed system is to enhance the quality of a child's sleep in the car seat by monitoring and regulating these conditions.

II. PROPOSED CONTRIBUTIONS

AngelRide is an autonomous system designed to help drivers stay focused by monitoring the child in the car seat. The system automatically detects when a child is seated and activates its features accordingly. A robotic mechanism reduces sunlight exposure to create a more comfortable sleep environment. Smart climate control functions adjust temperature and provide proper ventilation. Additionally, ambient noise is managed through AngelRide's integrated speaker system. The system is capable of detecting potential dangers and alerting the driver accordingly. By improving the child's comfort and minimizing distractions, AngelRide enhances both child and driver safety, ultimately reducing the risk of accidents.

A. NOVEL SOLUTIONS PROPOSED

- The system is fully automated to ensure a high quality of sleep for the child.
- A robotic mechanism is employed to minimize sunlight exposure and create a more comfortable environment for the child.
- The system monitors and controls the climate around the car seat to ensure proper ventilation and maintain a comfortable environment for the child.
- The system plays lullaby music to help the child relax and fall asleep more easily.
- A notification is sent to the driver if the system detects that the child is in danger.

B. PROBLEM STATEMENT

Children require high-quality sleep to support their physical and cognitive development [5]–[7]. However, sleep quality can be significantly influenced by environmental factors. Sleeping in a car seat often results in lower-quality sleep, which may lead to restlessness and discomfort. A restless child in a car seat can become a source of distraction for the driver, increasing the risk of accidents. Factors such as sunlight, noise, and temperature can further disrupt the child's sleep during travel.

III. RELATED WORK

This paper proposes a novel connection between driver safety and child care, two areas traditionally addressed separately in previous research. Most existing studies focus either on child monitoring or driver safety, with few examining how one influences the other. Poor sleep quality in child passengers can lead to increased driver distraction, posing a serious safety risk. Minimizing such distractions is essential to protecting children's lives. A key contribution of this work is a fully automated system that enhances in-vehicle safety by improving the quality of a child's sleep, allowing the driver to remain focused on the road.

Beyond the relationship between child care and driving, sleep quality monitoring has been extensively studied in other domains. A variety of sensors, combined with convolutional neural network (CNN) models, have been used to address limitations of traditional polysomnography (PSG) tests, as demonstrated in [8]. SaYoPillow is a smart device developed to explore the relationship between stress and sleep using sensor data secured through blockchain technology [9]. An integrated approach that combines self-reported data with objective measurements from wearable devices is proposed in [10]. Deep Sleep, a mobile application, connects university students with psychologists to improve sleep quality through guided support [11]. While these efforts focus primarily on enhancing sleep quality in stationary or clinical environments, the proposed AngelRide system applies smart technology specifically designed to improve sleep quality for children in car seats, addressing sleep needs in a mobile and often overlooked context.

In terms of driver safety, detecting, notifying, and preventing vehicle accidents using various sensors and GPS-based alerts to nearby drivers is discussed in [12]. Sensors embedded in the driver's seat have also been used to detect accidents and transmit the driver's condition and location to emergency responders [13]. To reduce emergency response times, fog computing has been applied to accelerate communication between vehicles and emergency departments [14]. BACTmobile leverages physiological signals, psychological behavior, and physical activity data to estimate a driver's blood alcohol concentration (BAC) levels [15]. While these studies offer valuable advancements in vehicle and driver-focused safety, they often overlook the condition and safety of passengers. Table I presents a concise overview of the current literature and its associated limitations. In contrast, the proposed AngelRide system addresses this gap by focusing specifically on child passengers, enhancing overall vehicle safety by improving child comfort and reducing distractions for the driver.

IV. PROPOSED SYSTEM: ANGELRIDE

A. SYSTEM OVERVIEW

The AngelRide system is designed with a hierarchical structure comprising three distinct levels, each responsible for specific functionalities, as illustrated in Fig.1. The system operates fully automatically, starting with the first level, known as the Controller, and ending with the Driver Notification, as shown in Fig.2. The controller level includes two main functions: baby detection, which activates when a child is seated in the car seat, and eye tracking, which depends on the baby detection function. The eye tracking module identifies signs of drowsiness or sleep by monitoring the child's eyes. The primary objective of this level is to activate or deactivate the entire system based on the child's presence and state.

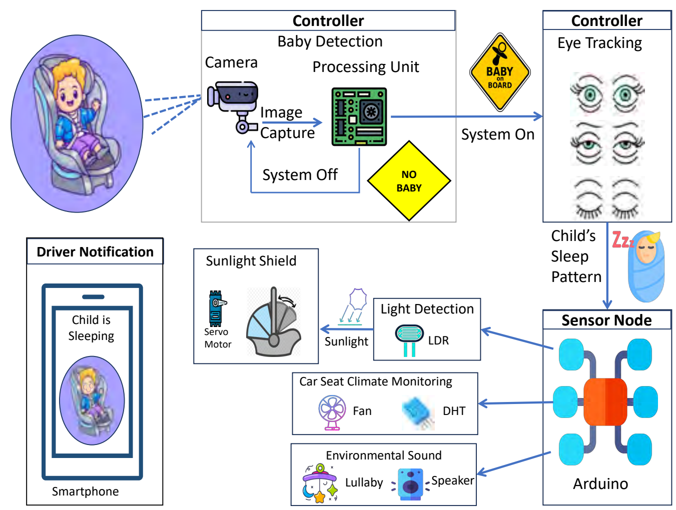


Fig. 1: AngelRide System Overview.

The second level, referred to as the Sensor Node, is responsible for monitoring the child's sleep conditions. It includes three key functions: Light Detection, Car Seat Climate Monitoring, and Environmental Sound Management. These functions integrate various sensors and actuators to enhance the quality of the child's sleep while seated in the car seat.

The third level is called Driver Notification. This level is designed to alert the driver via smartphone when the system fails to maintain optimal sleep quality for the child. The Controller level communicates with the Driver Notification level using the Global System for Mobile Communications (GSM) protocol to transmit alerts. AngelRide, as a smart and autonomous system, is developed to improve sleep quality for children in car seats while simultaneously reducing driver stress.

B. CONTROLLER LEVEL

The Controller level includes two main functions: baby detection and eye tracking. The eye tracking function is

TABLE I: Summary of Related Work

Study	Processing Unit	Focus and Contribution
Adithya *et al.* [8]	Sensors to DP model	Addressed limitations of traditional PSG tests using sensors and CNN models.
Rachakonda *et al.* [9]	Local device & blockchain	Smart device that explores the relationship between stress and sleep; sensor data secured through blockchain.
Konstantoulas *et al.* [10]	Cloud	Integrated approach to sleep monitoring that combines self-reported and wearable data.
Castilla *et al.* [11]	Mobile app	App connecting students to psychologists to improve sleep quality.
Barman *et al.* [12]	Edge + cloud	Vehicle-accident detection and prevention using sensors plus GPS-based alerts.
Almohsen *et al.* [13]	Edge + cloud	Driver-seat sensors detect accidents and transmit condition/location to responders.
Dar *et al.* [14]	Fog computing	Fog-based architecture to shorten emergency-response times.
Rachakonda *et al.* [15]	Edge + cloud	BAC estimation from physiological, psychological and behavioral data.
Alkinani (**proposed**)	Edge + cloud	Smart system that improves a child's sleep in car seats, reducing driver distraction and enhancing overall safety.

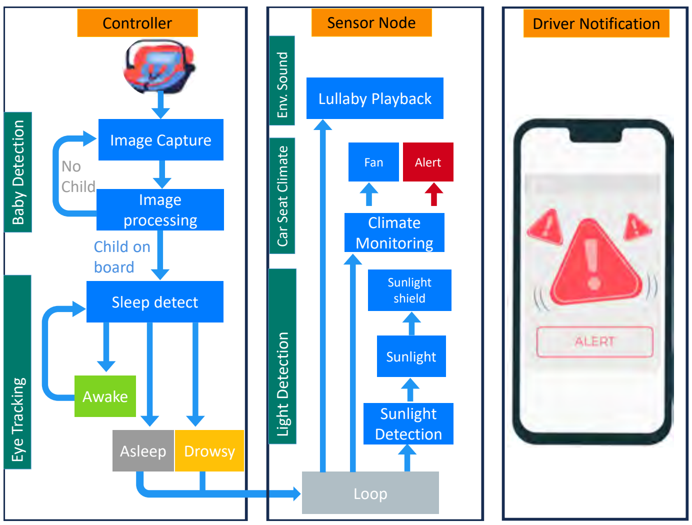


Fig. 2: AngelRide System Workflow.

activated only after the system confirms that a child is seated in the car seat, as outlined in Algorithm 1. This level consists of two components, as illustrated in Fig. 3. A camera serves as the sole input to the processing unit at this level.

Algorithm 1 Overview of Controller Level

```
Initialize system
while system is running do
  Capture image from camera
  Run YOLOv11 model for child detection
  if child is detected then
    Proceed to EyeTracking()
    Measure eye state
    if eye state = 1 then
      {Awake}Deactivate Sensor Node.
    else if eye state = 2 or eye state = 3 then
      {Asleep or Drowsy}Activate Sensor Node
    end if
  else
    Remain in BabyDetection() loop
  end if
end while=0
```

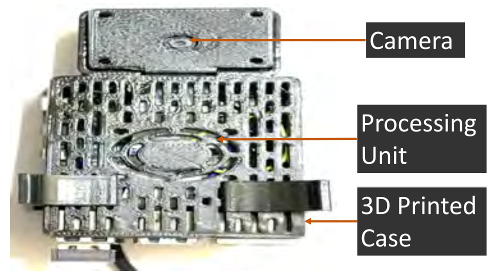


Fig. 3: Controller-Level Component.

1) BABY DETECTION: Captured images are first processed by the baby detection module, which uses object detection to identify the presence of a child in the car seat. The captured image is processed by the YOLOv8 model to identify the presence of a child. The primary objective of this function is to activate the AngelRide system once a child is detected.

2) EYES TRACKING: The eye-tracking function is triggered following successful child detection by the preceding module. To analyze the captured image and monitor the child's eye state, the system utilizes the Dlib pre-trained model, as described in [16]. This module classifies the eye state into one of three conditions: awake, asleep, or drowsy. Upon detecting a drowsy or asleep state, the system activates the Sensor Node level to enhance the surrounding environment, thereby promoting better sleep quality for the child.

C. SENSOR NODE LEVEL

The Sensor Node level includes three main functions designed to enhance the child's sleep quality. This level is activated when the child falls asleep, triggered by a signal from the Controller level. The steps involved in each function are outlined in Algorithm 2. The three functions are: Light Detection, Car Seat Climate Monitoring, and Environmental Sound Management. The Light Detection function helps protect the child from direct sunlight. The Car Seat Climate function monitors and regulates temperature and humidity to maintain a comfortable environment. The Environmental Sound function improves sleep quality by playing lullaby music.

1) LIGHT DETECTION: Although sunlight may have health benefits, it can negatively impact sleep quality [17]. The first function of the Sensor Node level focuses on reducing

Algorithm 2 Overview of Sensor Node

Signal is received from controller level
while Child is sleeping **do**
  Light Detection ()
  if Sunlight (Lux) $> 400lux$ **then**
    Servo Motor turns the shield 90 degrees.
  end if
  Car Seat Climate () {Check temperature difference between car seat and surrounding environment}
  if $|T_1 - T_2| > 3°$C **then**
    Turn on Fan
  else
    Trun off Fan
  end if
  if $TempSeat > 30°C$ **then**
    Trigger alert
  end if
  Environmental Sound ()
  LullabyPlayback()
end while=0

sunlight exposure to promote better sleep. Light intensity is detected using the VEML7700 sensor. When luminance exceeds 400 lux, sunlight is considered present [18]. In response, a sunlight shield is activated to protect the child. This shield is controlled by two high-quality MG995 servo motors, each capable of moving loads up to 9.40 kg [19]. Climate conditions inside the car seat are monitored in the subsequent function.

2) CLIMATE MONITORING: The car's air conditioning system may not always maintain a suitable environment for a child to sleep comfortably in the car seat. To address this, the Sensor Node level continuously monitors the temperature at the child's seat, regardless of whether sunlight is present. Two DHT sensors are used to compare temperatures: sensor T_1 is placed inside the child's car seat, while sensor T_2 is positioned at the driver's seat. The fan state, denoted as S_{fan}, is activated based on the computed temperature difference. An alert signal, A, is triggered in the event of a potential heatstroke condition. A heatstroke condition is defined as occurring when the temperature inside the car exceeds 40°C [20]. The fan control logic is defined as follows:

$$S_{\text{fan}} = \begin{cases} 1, & \text{if } |T_1 - T_2| > 3°\text{C} \\ 0, & \text{otherwise} \end{cases} \tag{1}$$

The alert trigger condition is defined as:

$$A = \begin{cases} 1, & \text{if TempSeat} > 30°\text{C} \\ 0, & \text{otherwise} \end{cases} \tag{2}$$

3) SOUND ENVIRONMENTAL: Playing lullaby music helps relax the child and improve sleep quality [21]. In addition to its calming effect, the music also helps mask ambient car noise and can serve as an indirect indicator to the driver that the child is drowsy or asleep. This function notifies the driver when the child falls asleep or wakes up, using audio cues to maintain the driver's focus on the road. The music playback is automatically stopped once the child wakes up.

V. DRIVER CHILD TRACKER

To help the driver maintain focus on the road, real-time updates about the child's state are minimized to reduce potential distractions. In the event that the system detects a danger to the child, the driver receives an immediate phone call alert. This notification prompts the driver to safely stop the vehicle and check the child's condition.

VI. EXPERIMENTAL RESULTS

A. COMPUTER VISION EVALUATION

1) Models: The Controller level hosts two models—baby detection and eye tracking—which are deployed on a Raspberry Pi 4 Model B with 4 GB of RAM. The baby detection model, YOLOv11m, is used to identify the presence of a child in the car seat. It was trained on a local machine equipped with an NVIDIA GeForce RTX 2080 SUPER GPU and 32 GB of RAM. The training process took approximately 10 hours for 100 epochs.

Fig.4 presents key performance metrics for the YOLOv11 model, including mAP@50 (mean average precision at 50% IoU), mAP@50-90, precision, and recall. Additionally, training and validation losses—box loss, classification loss (cls loss), and distribution focal loss (dfl loss)—are illustrated. The model was evaluated on a test set, and the results demonstrate strong performance, as shown in Fig.5.

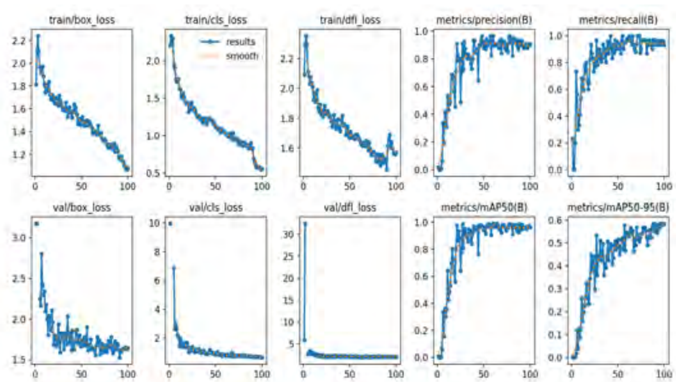


Fig. 4: YOLOv11 Evalutation.

The second model utilizes the Dlib library for real-time face analysis. As shown in Fig. 6, the eye-tracking model identifies three possible states: Awake, Drowsy, and Sleep. Dlib begins by detecting faces using a Histogram of Oriented Gradients (HOG) descriptor combined with a linear SVM classifier to localize frontal faces. To extract precise facial features, a 68-point facial landmark predictor is employed, with the detected landmarks represented as white dots in Fig. 6. The system specifically focuses on the eye regions, which are defined by landmarks 36–41 for the left eye and 42–47 for the right eye. The Eye Aspect Ratio (EAR) formula [22] is then used to evaluate the child's eye state:

(a) Ground Truths

(b) Predictions

Fig. 5: Performance Results of the Baby Detection Model

$$\text{EAR} = \frac{|p_2 - p_6| + |p_3 - p_5|}{2 \cdot |p_1 - p_4|} \tag{3}$$

Based on the EAR value, if the result is below 0.21, the child is considered asleep. If the EAR is above 0.25, the child is classified as awake, and if it falls between 0.21 and 0.25, the child is considered to be in a drowsy state.

2) Dataset: The high-quality dataset was trained to detect the child prenst on car seat by YOLOv11 [23]. It contains 360 images at a resolution of 640×640, which were split into training, validation, and test sets. Data augmentations, including blur, flipping, and Rotation, were applied to improve dataset quality and model robustness. The dataset comprises images taken from diverse angles and environmental conditions, resulting in a high-quality and comprehensive dataset.

VII. CONCLUSION AND FUTURE WORK

Potential distractions for the driver pose significant risks to child safety. Traditional child car seats lack integrated care systems, which can increase driver stress and reduce overall road safety. To address this issue, the proposed work introduces a fully automated system that enhances both driver focus and child well-being by improving the child's sleep quality during travel.

The system integrates computer vision models with IoMT technologies to continuously monitor the child while in the car seat. The YOLOv11 model is employed to detect the presence of a child, and an eye-tracking module follows to determine the child's sleep state. A multi-sensor setup then creates an optimal environment by regulating light, temperature, humidity, and sound to support and maintain the child's sleep. By increasing the child's comfort, the system effectively reduces driver stress and helps prevent distractions.

For future work, the scope of child care will be expanded by incorporating additional features such as feeding support and in-seat entertainment. These enhancements aim to further improve the travel experience for both the child and the driver, promoting greater safety and comfort

REFERENCES

[1] National Highway Traffic Safety Administration, "Distracted driving," https://www.nhtsa.gov/risky-driving/distracted-driving, 2023, accessed: 2025-04-08. [Online]. Available: https://www.nhtsa.gov/risky-driving/distracted-driving

[2] Law Brothers, "What percentage of car accidents are caused by driver error?" accessed: 2025-04-08. [Online]. Available: https://lawbrothers.com/what-percentage-of-car-accidents-are-caused-by-driver-error/

[3] National Highway Traffic Safety Administration, "NHTSA Releases 2022 Traffic Deaths, 2023 Early Estimates," https://www.nhtsa.gov/press-releases/2022-traffic-deaths-2023-early-estimates, 2024, accessed: 2025-04-08. [Online]. Available: https://www.nhtsa.gov/press-releases/2022-traffic-deaths-2023-early-estimates

[4] Vern Fonk Insurance, "5 tips for driving with children," https://www.vernfonk.com/blog/cars/5-tips-for-driving-with-children/, 2020, accessed: 2025-04-08.

[5] Mayo Clinic Health System, "Sleep: An essential element of success for children," accessed: 2023-10-27. [Online]. Available: https://www.mayoclinichealthsystem.org/hometown-health/speaking-of-health/sleep-an-essential-element-of-success-for-children

[6] ——, "Is your child getting enough sleep?" accessed: 2023-10-27. [Online]. Available: https://www.mayoclinichealthsystem.org/hometown-health/speaking-of-health/is-your-child-getting-enough-sleep

[7] Sleep Foundation, "Children and sleep," accessed: 2023-10-27. [Online]. Available: https://www.sleepfoundation.org/children-and-sleep

[8] A. SM, A. P, A. Loy, A. George, and S. Sreekumar, "A deep learning framework for comprehensive sleep analysis and quality tracking," in *Proceedings of IEEE 2nd International Conference on Data, Decision and Systems (ICDDS)*, 2023, pp. 1–6.

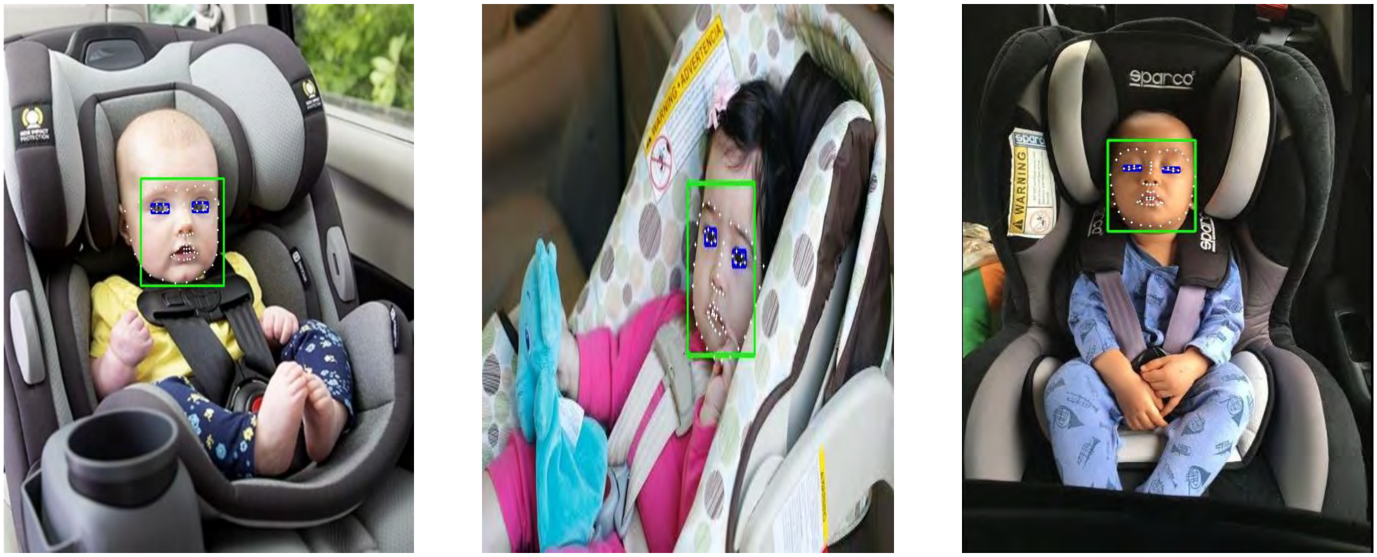
[9] L. Rachakonda, A. K. Bapatla, S. P. Mohanty, and E. Kougianos, "Sayopillow: Blockchain-integrated privacy-assured iomt framework for stress management considering sleeping habits," *IEEE Transactions on Consumer Electronics*, vol. 67, no. 1, pp. 20–29, 2021.

[10] I. Konstantoulas, O. Kocsis, N. Fakotakis, and K. Moustakas, "An approach for continuous sleep quality monitoring integrated in the smartwork system," in *Proceedings of IEEE International Conference on Bioinformatics and Biomedicine (BIBM)*, 2020, pp. 1968–1971.

[11] S. S. C. Castilla, C. B. Del Pozzo, and E. A. Cerna, "Technological solution to improve sleep quality in university students," in *Proceedings of Congreso Internacional de Innovación y Tendencias en Ingeniería (CONIITI)*, 2022, pp. 1–4.

[12] S. Barman, M. F. Bin Hafiz, and N. A. Khan, "An iot-based smart system for the detection, notification and prevention of vehicle accidents," in *Proceedings of 6th International Conference on Electrical Engineering and Information Communication Technology (ICEEICT)*, 2024, pp. 1169–1174.

[13] M. K. Almohsen, R. k. alonzi, T. H. Alanazi, S. N. BinSaif, and M. M. almujally, "Smart car seat belt: Accident detection and emergency services in smart city environment," in *Proceedings of 1st International Conference on Artificial Intelligence and Data Analytics (CAIDA)*, 2021, pp. 109–114.



(a) State=Awake (b) State= Drowsy (c) State= Sleep

Fig. 6: Eyes Traking

[14] B. K. Dar, M. A. Shah, S. U. Islam, C. Maple, S. Mussadiq, and S. Khan, "Delay-aware accident detection and response system using fog computing," *IEEE Access*, vol. 7, pp. 70 975–70 985, 2019.

[15] L. Rachakonda, A. K. Bapatla, S. P. Mohanty, and E. Kougianos, "Bactmobile: A smart blood alcohol concentration tracking mechanism for smart vehicles in healthcare cps framework," *SN Computer Science*, vol. 3, no. 3, p. 236, 2022. [Online]. Available: https://doi.org/10.1007/s42979-022-01142-9

[16] D. E. King, "Dlib-ml: A machine learning toolkit," *Journal of Machine Learning Research*, vol. 10, pp. 1755–1758, 2009.

[17] G. Düzgün and A. Durmaz Akyol, "Effect of natural sunlight on sleep problems and sleep quality of the elderly staying in the nursing home," *Holistic Nursing Practice*, vol. 31, no. 5, pp. 295–302, 2017.

[18] Vishay Intertechnology, Inc., *VEML7700: High Accuracy Ambient Light Sensor with I2C Interface*, November 2024, rev. 1.8. [Online]. Available: https://www.vishay.com/docs/84286/veml7700.pdf

[19] T. Pro, "Mg995 high torque metal gear servo motor," 2023, accessed: April 20, 2025. [Online]. Available: https://www.servodatabase.com/servo/towerpro/mg995

[20] National Highway Traffic Safety Administration, "Child safety," https://www.nhtsa.gov/road-safety/child-safety, n.d., [Accessed: Apr. 20, 2025].

[21] A. S. Turkmen, N. C. Sahiner, and S. Inal, "The effectiveness of using lullaby and massage alone and together in assisting kindergarten students to fall asleep," *International Archives of Health Sciences*, vol. 9, no. 1, pp. 70–75, 2022.

[22] T. Soukupová and J. Čech, "Real-time eye blink detection using facial landmarks," in *21st Computer Vision Winter Workshop*. CEUR Workshop Proceedings, 2016, pp. 1–8.

[23] IDP Dataset, "Baby monitoring 4 dataset," https://universe.roboflow.com/idp-dataset/baby-monitoring-4, May 2023, accessed: 2025-04-23.