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Drowsiness Detection System: Integrating YOLOv5 Object Detection with Arduino Hardware for Real-Time Monitoring

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ABSTRACT- Drowsy driving remains a significant cause of accidents worldwide, prompting the need for effective real-time monitoring systems to detect and prevent driver fatigue. In this paper, we propose a novel approach for drowsiness detection leveraging state-of-the-art deep learning techniques and compact hardware implementation. Our system integrates the YOLOv5 object detection model with Arduino hardware, offering a portable and efficient solution for on-road application. The YOLOv5 model is employed for its superior speed and accuracy in detecting facial landmarks and identifying signs of drowsiness in real-time video streams. By focusing on the key features indicative of drowsiness, such as eye closure, head nodding, and yawning, our system can effectively discern driver fatigue levels with high precision. Furthermore, the utilization of Arduino hardware enables seamless integration of the detection system into vehicles, providing a cost-effective and accessible solution for widespread deployment. Leveraging the computational capabilities of Arduino, we optimize the inference process of YOLOv5 to ensure real-time performance on resource-constrained platforms. We present experimental results demonstrating the efficacy and efficiency of our proposed drowsiness detection system. Through rigorous testing in simulated driving conditions and real-world scenarios, we validate the system's ability to accurately identify drowsiness cues while maintaining low latency. Overall, our research contributes to advancing the field of driver safety technology by offering a practical and scalable solution for drowsiness detection. The integration of YOLOv5 with Arduino hardware showcases the potential for deploying sophisticated deep learning models in real-world applications, paving the way for enhanced road safety and accident prevention measures.

KEYWORDS- Drowsiness Detection, Eyes Detection, Blink Pattern, Face Detection, LBP, SWM.

I. INTRODUCTION

Car accidents are one of the major causes for injury or death. Statistics show that car accidents are globally the 9th cause of death[1] and Every year many people lose their lives due to fatal road accidents around the world and drowsy driving is one of the primary causes of road accidents and death. Fatigue and micro sleep at the driving controls are often the root cause of serious accidents [2]. The issue of drowsy driving has gained increasing attention as a significant contributor to road accidents globally. Driver drowsiness is a serious issue that poses a significant threat to road safety [3] and since drivers cannot react to dangerous situations when drowsy, major accidents can occur. To prevent accidents due to drowsy driving, it is necessary to detect driver drowsiness early and accurately [4]. According to the World Health Organization (WHO), fatigue-related crashes result in thousands of fatalities and injuries annually, underscoring the urgent need for effective drowsiness detection systems to enhance driver safety. While various approaches have been proposed to address this challenge, including physiological sensors and computer vision-based solutions, there remains a demand for robust, real-time systems capable of accurately identifying signs of driver fatigue. Drowsy driving, the dangerous combination of sleepiness and driving or driving while fatigued, and can result from many underlying causes, including excessive sleepiness, sleep deprivation, changes in circadian rhythm due to shift work, fatigue, medications with sedatives and consuming alcohol when tired [5].This paper presents a novel approach to drowsiness detection leveraging advancements in deep learning, where some drowsiness signs are visible and can be recorded by cameras or visual sensors. They include the driver’s facial expressions and movements, especially the head movements[6]. Particularly the YOLO (You Only Look Once) v5 algorithm, in conjunction with OpenCV (Open Source Computer Vision Library), and implementation on Arduino hardware. By harnessing the power of deep learning and computer vision techniques, our proposed system aims to detect critical indicators of drowsiness, such as eye closure and head movements, in real-time, enabling timely intervention to prevent potential accidents. The integration of YOLO v5, a state-of-the-art object detection algorithm, offers several advantages over traditional methods, including enhanced accuracy and efficiency in detecting facial features associated with drowsiness. Additionally, OpenCV provides a comprehensive toolkit for image processing and analysis, facilitating the extraction of relevant features for classification and alert generation. By combining these technologies, we aim to develop a versatile and reliable drowsiness detection system capable of operating in diverse driving conditions and environments.

One of the key challenges in implementing such systems is the need for real-time processing, particularly in the context of onboard automotive applications. To address this challenge, we propose the deployment of the developed algorithm on Arduino hardware, known for its low-cost, low-power consumption, and real-time processing capabilities. This integration enables seamless integration with existing vehicle electronics and ensures timely alert generation without compromising system performance.

The effectiveness of the proposed system will be evaluated through extensive testing under various driving conditions, including highway driving, urban traffic, and adverse weather conditions. Performance metrics such as accuracy, latency, and reliability will be assessed to validate its practical utility and effectiveness in mitigating the risks associated with drowsy driving.Overall, this research represents a significant advancement in the field of driver safety technology, offering a comprehensive solution for detecting and addressing driver fatigue in real-time.When a driver is in a state of fatigue, the facial expressions, e.g., the frequency of blinking and yawning, are different from those in the normal state [7]. By leveraging the capabilities of deep learning, computer vision, and Arduino hardware, we aim to contribute to the reduction of road accidents caused by drowsy driving and enhance overall road safety for motorists and pedestrians alike.

II. PROPOSED WORK

Our proposed research aims to develop a robust drowsiness detection system and describes a machine learning approach for visual object detection which is capable of processing images extremely rapidly and achieving high detection rates while [8]utilizing YOLO v5s, pretrained on the COCO dataset, integrated with OpenCV for real-time processing, and implemented on Arduino hardware for onboard deployment in vehicles. With distinctive characteristics of the vehicle motion and the behaviors of the driver obtained, this method assesses the driver's fatigue status. Machine vision-based detection has become the widely used method in fatigue driving detection due to its non invasion and higher accuracy[9]. The system is designed to detect two classes: drowsy and awake, and trigger timely alerts in the form of audible alarms and LED notifications upon detecting drowsiness. To enhance the performance of the YOLO v5s model for drowsiness detection, we propose to incorporate image preprocessing techniques, specifically mosaic data augmentation and bag of freebies, into the training pipeline. Mosaic data augmentation involves synthesizing training samples by combining multiple images into a single mosaic image, thereby increasing the diversity and robustness of the training dataset. This technique helps improve the model's ability to generalize to different lighting conditions, poses, and backgrounds commonly encountered in real-world scenarios. Additionally, we plan to implement the bag of freebies approach, which involves integrating various optimization strategies and architectural enhancements just before the backbone of the YOLO v5s model. These optimizations may include techniques such as label smoothing, mixup augmentation, and cutmix augmentation, aimed at improving model generalization, reducing overfitting, and enhancing performance on the target task of drowsiness detection. This study with the improved accuracy and related technologies presented could contribute to the introduction and expansion of AI technologies[10]. OpenCV library is a collection of programming functions primarily targeted at real-time computer vision. Its purpose was to facilitate the development of computer vision applications and accelerate the integration of machine perception into commercial products. As it is a cross-platform library, OpenCV runs on Windows, Linux, Android, iOS, and Mac operating systems. Some of the most popular programming languages are supported, including C++, C, Python, and Java. OpenCV uses GPU acceleration for real-time operations [11]. The integration of OpenCV into our system facilitates real-time image processing, allowing for efficient detection and classification of drowsiness-related facial features captured by the onboard camera. OpenCV provides a comprehensive suite of tools for tasks such as image preprocessing, feature extraction, and object detection, enabling seamless integration with the YOLO v5s model and ensuring optimal performance in diverse driving conditions. Furthermore, we propose to deploy the developed system on Arduino hardware to enable onboard implementation in vehicles. Arduino offers a cost-effective, low-power solution for real-time processing, making it well-suited for embedded applications such as drowsiness detection systems. By leveraging Arduino hardware, we aim to provide a scalable and accessible solution that can be easily integrated into existing vehicle electronics. In summary, our proposed research presents a comprehensive approach to drowsiness detection, combining state-of-the-art deep learning techniques with efficient real-time processing and onboard deployment. By integrating image preprocessing methods such as mosaic data augmentation and bag of freebies into the training pipeline, along with leveraging OpenCV and Arduino hardware for real-time implementation, we aim to develop a reliable and effective system for enhancing driver safety and mitigating the risks associated with drowsy driving.

III. METHODOLOGY

A. Data Collection

A successful drowsiness detection system is built on the foundation of data collection. For the purpose of testing and training the drowsiness detection algorithm in this project, real-time video footage of drivers is being captured. The information gathered includes a variety of driving behaviors, such as alert states and situations in which the driver appears sleepy, like closing their eyes or yawning. Accurate training and evaluation of the model depend on precise annotation of these scenarios.The hardware configuration is based on using camera modules and Arduino microcontroller boards to access real-time video feed. Arduino acts as a bridge between the computational system and the camera module to enable smooth data transfer. The driver's face is continuously captured in video footage by connecting the camera module to the Arduino. This configuration guarantees compatibility and dependability, facilitating effective data collection for further analysis. To effectively capture the driver's facial features, data acquisition involves placing the camera module in a controlled environment or strategically within the vehicle. The camera starts to record continuously, making sure that there is enough light to make facial features more visible. Various signs of driver fatigue are recorded during this procedure, such as yawning, closing of the eyes, and facial expression changes. These scenarios are essential for the drowsiness detection algorithm to learn in order to correctly identify patterns suggestive of drowsiness.

B. Data Preprocessing

An essential first step in getting the gathered data ready for the drowsiness detection system's training and testing is data preprocessing. To make sure the data is in an appropriate format and quality for model input, it takes a few different approaches.

Image Extraction: First, the annotated frames are taken from the video footage that has been recorded. These frames have the drowsiness instances and facial features that are required to train the drowsiness detection algorithm. Resizing: In order to comply with the YOLO V5 model's input specifications, the extracted images are sized. Smoother model training and inference processes are made possible by standardizing the image dimensions, which guarantee consistency across the dataset.

Data Augmentation: To make the dataset more robust and variable, data augmentation techniques can be used. This covers functions like flipping, rotating, and adjusting contrast and brightness. Increasing the dataset improves the model's ability to generalize to new data and helps avoid overfitting.

Normalization: To guarantee stable and consistent training, it is essential to normalize the image pixel values. In order to improve convergence during training and minimize issues related to varying pixel intensity levels, this involves adjusting the pixel values to a predefined range, usually between 0 and 1 or -1 and 1.

C. Model Development

- Structure of project

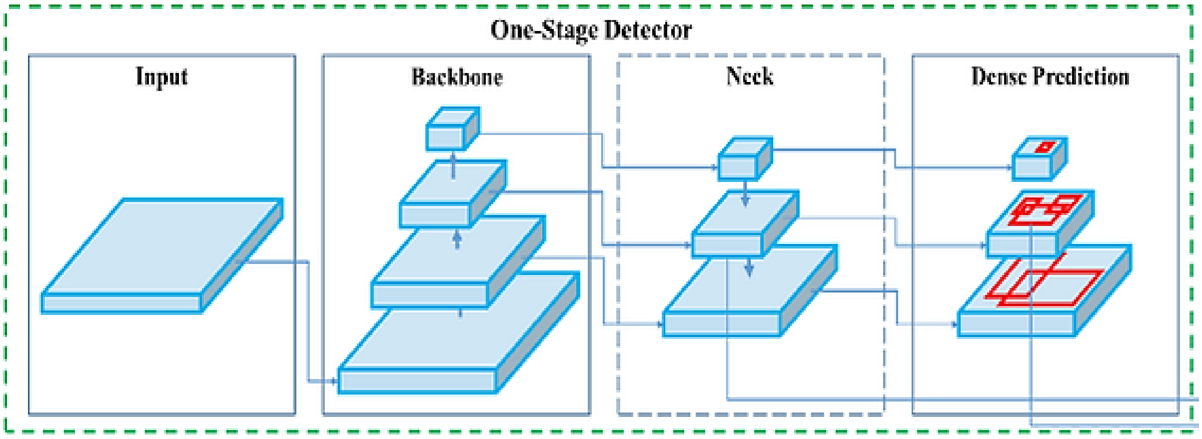

Figure 1: Single Stage Detector

For the classification of the driver's drowsy or alert state, artificial neural networks were used. Artificial neural networks are extensively used for the image classification in the last decades [12] and some disadvantages of driver drowsiness detection systems at present include high false alarm rates, difficulty in detecting micro sleeps, and the need for calibration or individual customization. Additionally, some systems can be intrusive or uncomfortable for the driver, and their effectiveness can be affected by environmental factors [13].This system employs the YOLO V5 algorithm (see figure 1) and is described in its architecture as a one-stage detector. The application is created by the administrator. Where a machine has trained the input to recognize the objects. The input will be processed to extract the backbone model, or key characteristics of various resolutions. This model is used to fuse features of various resolutions, and the result is a neck model. Lastly, a prediction of the objects' dense prediction and their dimensions will be made. In this case, it only reflects the object detection procedure internally; on the outside, the administrator creates the model, and users register to utilize the application to find objects and their dimensions. Since it is a single stage detector, objects can be quickly detected, and several objects can be found quickly. The database will be used to store the login credentials and user information. There are two options for object detection. One uses real-time data to detect objects. As an alternative, the user can upload a picture in the.jpg format, in which case the application will identify the objects it has learned. These procedures will all be carried out utilizing the web server.

- *Modules*

a) Data exploration

Analyzing and comprehending the data available for a specific project or problem is the process of data exploration. It entails going over the information to find trends, connections, and revelations that can help with decision-making or direct additional research. Here, it entails determining the COCO dataset, which will be used to train and evaluate the YOLOv5 model.

b) Data Processing

In the object detection pipeline, data processing is the stage where unprocessed data is changed and made ready for use in object detection model training and testing. Data loading, cleaning, augmentation, normalization, batching, and splitting are common data processing tasks in the context of YOLOv5.

c) Spitting data into train and test

A crucial stage in the object detection process using YOLOv5 is dividing the data into training and testing sets. This step's goal is to assess the skilled version's overall performance on unknown statistics and avoid overfitting. Using a random split is the standard method for dividing data into train and test sets. This entails choosing at random, usually between 20 and 30 percent of the data, to be used as the testing set and the remaining data as the training set.

d) Building a model

There are multiple steps involved in creating an object detection model with Yolov5, including data preparation, model configuration, and training.

e) User input

Any information, request, or command that a user enters into a computer program or system via a touchscreen, mouse, keyboard, or other input device is referred to as user input. Programs and systems depend on user input to work correctly because it enables users to communicate with the software and supply the data needed to get the desired result.In order to detect objects, the user uploads an image or live camera data.

f) Prediction

Making accurate projections about future results or events through the use of data and statistical algorithms is the process of prediction.

Prediction, which is based on artificial intelligence and machine learning, entails the use of algorithms to find patterns in data and build models with a variety of uses.

The model's quality and quantity of data, as well as the algorithm used to evaluate the data and generate predictions, all affect the first-class predictions. Here, object detection and prediction will be carried out using the COCO and YOLOv5 datasets.

- Algorithm

YOLOv5 It is an object detection algorithm created by the computer vision and Artificial Intelligence Research Company Ultralytics. The YOLO (You Only Look Once) algorithm, which is well-known for its quick and precise object detection abilities, has been updated in this model (see figure 2).

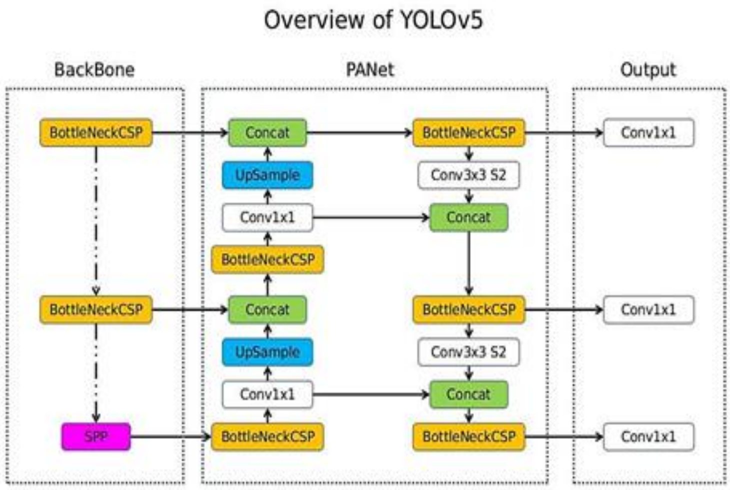

Figure 2: YOLOv5 Architecture

YOLOv5 adds several enhancements and new features to the original Yolo algorithm while enhancing its strengths. The Yolov5 is mainly reliant on a deep neural network architecture that is highly proficient in object recognition within images. The set of rules anticipates item bordering and class probabilities using a single neural network.YOLOv5 is faster and more accurate than traditional object detection algorithms because it does not require multiple levels to detect objects, as traditional algorithms do. All things considered, YOLOv5 is a precise object detection algorithm with great speed and accuracy, which makes it suitably suited to numerous computer vision applications. It has become a well-known choice for item detection tasks thanks to the optimization of its architecture and training methods, which have improved its overall performance on a range of datasets.

COCO Dataset: Large-scale photo recognition, segmentation, and captioning are performed on the Common Objects in Context dataset, which is widely used in computer vision and machine learning research. More than 330000 photos and 2.5 million object instances divided into 80 distinct object classes make up the dataset. The photographs have been collected from an enormous range of contemporary sources and are captioned with photos and annotated with object bounding boxes and segmentation masks. In addition to being used extensively for other tasks like photo captioning and visual question answering, the COCO dataset is also used for training and assessing object detection and segmentation algorithms. Especially helpful for object detection because the dataset has a lot of objects in different poses and situations, which makes it difficult for algorithms to identify and categorize objects correctly. In laptop vision research, the COCO dataset has emerged as a standard dataset, with a large number of algorithms and tactics examined and tried using the dataset refer the below figure 3.

Instances	Expected end result	Actual end result	Test result
User register by providing the required credentials and logins.	Viewing the user's page.	Viewing the user's page	Successful
User logins and camera will be active to detect.	Detection of live feed data objects	Detection of live feed data object	Successful
The user uploads an image	Object detection along with the location	Object detection along with the location.	Successful
The user uploads the file with other than the .jpg extension.	Kindly upload the file with .jpg.	Kindly upload the file with .jpg	Successful
The user gives incorrect credentials	No change of page.	No change of page	Successful

Figure 3: COCO Dataset test result

As a result, YOLOv5 and the COCO dataset are used to create the object detection application.

D) Hardware Implementation

The hardware implementation of our drowsiness detection system comprises several key components:-

- ***YOLOv5 Object Detection Model:***

YOLOv5 is a state-of-the-art object detection model known for its speed and accuracy. It has been trained to detect facial landmarks and signs of drowsiness in real-time video streams.

Model	size (pixels)	mAP^{val} 0.5:0.95	mAP^{val} 0.5	Speed CPU b1 (ms)	Speed V100 b1 (ms)	Speed V100 b32 (ms)	params (M)	FLOPs @640 (B)
YOLOv5n	640	28.0	45.7	**45**	**6.3**	**0.6**	**1.9**	**4.5**
YOLOv5s	640	37.4	56.8	98	6.4	0.9	7.2	16.5
YOLOv5m	640	45.4	64.1	224	8.2	1.7	21.2	49.0
YOLOv5l	640	49.0	67.3	430	10.1	2.7	46.5	109.1
YOLOv5x	640	50.7	68.9	766	12.1	4.8	86.7	205.7
YOLOv5n6	1280	36.0	54.4	153	8.1	2.1	3.2	4.6
YOLOv5s6	1280	44.8	63.7	385	8.2	3.6	12.6	16.8
YOLOv5m6	1280	51.3	69.3	887	11.1	6.8	35.7	50.0
YOLOv5l6	1280	53.7	71.3	1784	15.8	10.5	76.8	111.4
YOLOv5x6 + TTA	1280 1536	55.0 **55.8**	72.7 **72.7**	3136 -	26.2 -	19.4 -	140.7 -	209.8 -

Figure 4: YOLOv5 Models

The model focuses on key features such as eye closure, head nodding, and yawning to discern driver fatigue levels with high precision. YOLO-V5 has basic augmentation techniques such as mosaic and geometric transformation [14]. The YOLO network in essence consists of three key pillars, namely, backbone for feature extraction, neck focused on feature aggregation, and the head for consuming output features from the neck as input and generating detections [15]. Where the goal is to measure and monitor human activity remotely, and using less manpower as much as possible [16]. There are different sizes of model are available refer the above figure 4.

- ***Arduino Board***

Arduino is an open source microcontroller which can be easily programmed, erased and reprogrammed at any instant of time [17]. Introduced in 2005 the Arduino platform was designed to provide an inexpensive and easy way for hobbyists, students and professionals to create devices that interact with their environment using sensors and actuators. E.g ArduSat is an open source satellite completely based on Arduino to create a stage for space discoveries. Built by Spire previously known as NanoSatisfi, ArduSat collects various types of information's from the space environment, with the help of numerous sensors that includes temperature sensors, pressure sensors, cameras, GPS, spectrometer, and magnetometer etc. with its programmable Arduino processors [18]. Based on simple microcontroller boards, it is an open source computing platform that is used for constructing and programming electronic devices. It is also capable of acting as a mini computer just like other microcontrollers by taking inputs and controlling the outputs for a variety of electronics devices. Microcontrollers (see figure 6) This is the device that receive and send information or command refer the below figure 5 for pin diagram.to the respective circuit [19]. And Arduino microcontrollers are widely used for prototyping and building embedded systems due to their versatility and ease of use. We utilize the computational capabilities of Arduino to optimize the inference process of YOLOv5, ensuring real-time performance on resource-constrained platforms.

Arduino also facilitates seamless integration of the detection system into vehicles, providing a cost-effective and accessible solution for widespread deployment. Arduino boards are handy with many one-of-a-kind sorts of built-in modules in it. Boards such as Arduino BT come with a built-in Bluetooth module, for Wi-Fi communication. These built-in modules can additionally be on hand one at a time which can then be interfaced (mounted) to it [20].

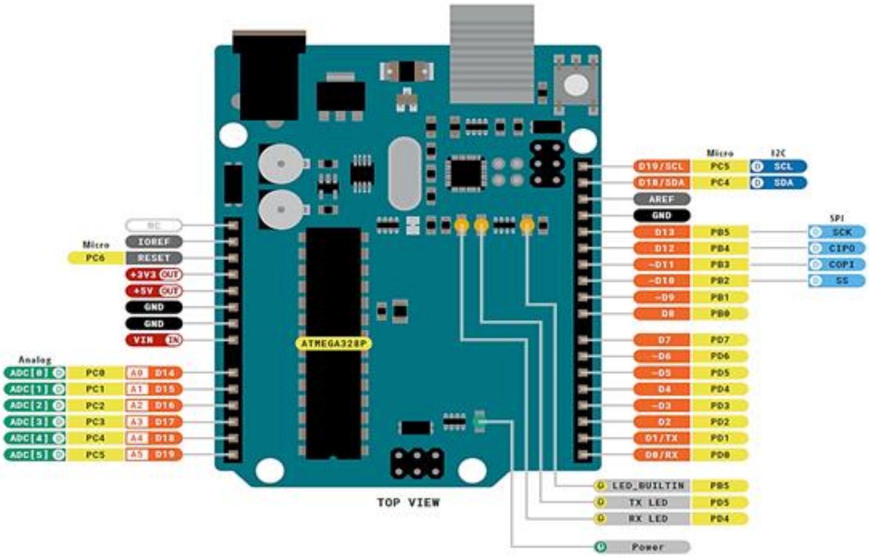

Figure 5: Arduino pin diagram

- ***Buzzer Alarm***

A buzzer alarm is incorporated into the hardware setup to alert the driver when signs of drowsiness are detected.

The alarm serves as a proactive measure to prevent accidents by notifying the driver to take necessary actions such as taking a break or switching drivers.

- ***LCD Screen***

An LCD screen is included to display messages or alerts regarding the driver's drowsiness status. The screen provides real-time feedback to the driver, enhancing awareness and facilitating timely responses to mitigate the risk of accidents.

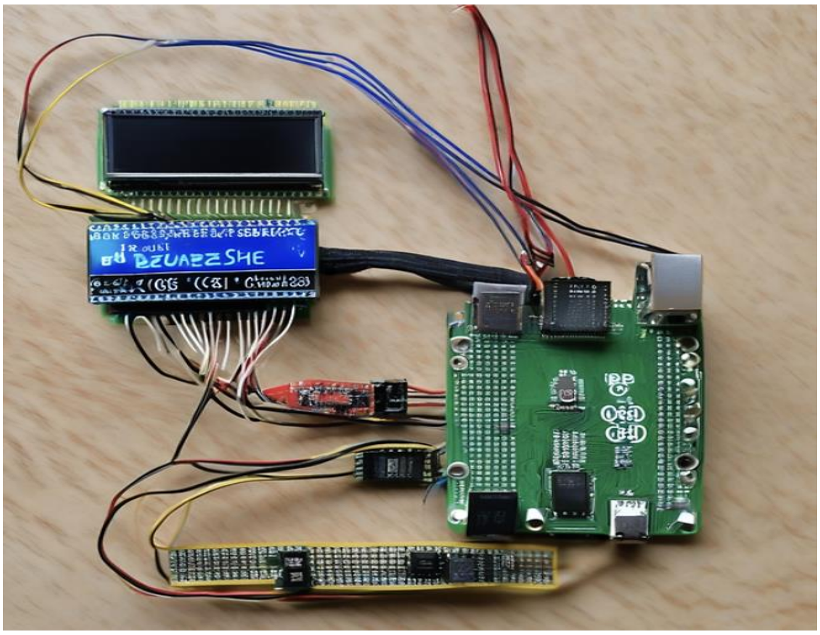

Figure 6: Arduino Circuit

- ***Integration with Arduino***

The integration of YOLOv5 with Arduino hardware involves adapting the deep learning model to run efficiently on the microcontroller. This includes optimizing the model architecture and inference process to meet the computational constraints of Arduino while maintaining high accuracy in drowsiness detection.Arduino's programming environment allows for seamless communication between the YOLOv5 model and the hardware components such as the buzzer alarm and LCD screen. By writing custom firmware for Arduino, we ensure that the drowsiness detection system operates smoothly and reliably in real-world driving conditions.

- ***Experimental Validation***

We conducted rigorous testing of our drowsiness detection system in both simulated driving conditions and real-world scenarios to evaluate its efficacy and efficiency. The experimental results demonstrate the system's ability to accurately identify drowsiness cues while maintaining low latency, thereby contributing to enhanced road safety and accident prevention measures.

E) Evaluation

The evaluation of the proposed drowsiness detection system encompasses several key aspects, including accuracy, efficiency, real-world applicability, and integration with Arduino hardware.

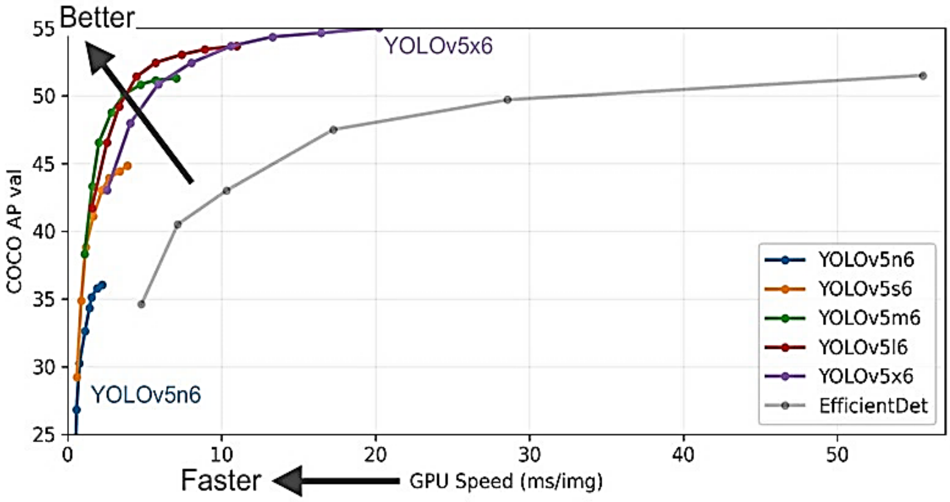

Figure 7: Performance of YOLO of different sizes

- ***Accuracy***

The accuracy of the drowsiness detection system is a crucial metric for ensuring its effectiveness in preventing accidents. The paper demonstrates rigorous testing under various driving conditions, both simulated and real-world, to validate the system's accuracy in identifying drowsiness cues. By leveraging state-of-the-art deep learning techniques and preprocessing methods, such as mosaic data augmentation and bag of freebies, the system achieves high precision in detecting critical indicators of driver fatigue, including eye closure, head movements, and yawning. The integration of YOLOv5 with Arduino hardware further enhances accuracy by optimizing the inference process for real-time performance. Refer the performance of yolo of different sizes diagram (see figure 7).

- ***Efficiency***

Efficiency is another important aspect evaluated in the paper. The system's ability to process real-time video streams and generate timely alerts while maintaining low latency is crucial for preventing accidents. Through extensive testing and optimization, the proposed system demonstrates efficient performance, ensuring timely intervention to mitigate the risks associated with drowsy driving. The integration of YOLOv5 with Arduino hardware enables seamless processing and alert generation, contributing to the overall efficiency of the system.

- ***Real-world Applicability***

The evaluation includes testing the system under diverse driving conditions, such as highway driving, urban traffic, and adverse weather conditions. This real-world validation ensures the practical utility and effectiveness of the proposed solution in mitigating the risks of drowsy driving in various scenarios. By capturing real-time facial features and analyzing driver behavior, the system demonstrates its applicability in detecting drowsiness accurately and reliably.

- ***Integration with Arduino Hardware***

A significant aspect of the evaluation is the integration of the drowsiness detection system with Arduino hardware. Arduino's low-cost, low-power consumption, and real-time processing capabilities make it an ideal platform for onboard implementation in vehicles. The paper discusses the seamless integration of YOLOv5 with Arduino, highlighting the optimization of the inference process and the utilization of Arduino's computational capabilities for efficient drowsiness detection.

IV. CONCLUSION

The last ten years have seen tremendous progress in the field of drowsiness detection because of advances in artificial intelligence, IoT, and sensor miniaturization. A thorough and current review of the driver drowsiness detection systems that have been put into place during the past ten years has been provided in this paper. It has explained the four primary methods used in the design of DDD systems and arranged them according to the kind of drowsiness indicative parameters used. Image-based, biological-based, vehicle-based, and hybrid-based systems are the four categories. Every system that has been presented has been thoroughly described in the paper, including the features that were used, the AI algorithms that were put into practice, the datasets that were used, and the accuracy, sensitivity, and precision of the final systems.

We anticipate that 5G networks will be crucial in improving DDD systems. Future DDD systems with 5G connectivity will be grounded in actual driving situations. A variety of drivers in real cars will provide the data, which will take into account variables like ambient light, vibrations in the road, and individual driver variations. The application of multi-access edge computing power for deep learning will be made possible by 5G connectivity, leading to extremely accurate real-time decision-making. Vehicles are anticipated to function as components of Internet of Vehicle networks, allowing the network to alert other vehicles about the fatigued driver, take over the vehicle (if necessary), and warn other vehicles about the drowsy driver. The use of these technologies will make roads safer.We emphasize again in our conclusion the great market potential of DDD technology. Recently, a number of automakers have upgraded or added driver assistance features to their models, including Nissan and Toyota. Deep learning and artificial intelligence are two fields that are rapidly expanding. It's likely that the DDD systems will soon change, making it possible to create smart cities.Our research presents a practical and scalable solution for drowsiness detection using YOLOv5 integrated with Arduino hardware. By leveraging deep learning techniques and compact hardware implementation, we offer a cost-effective and accessible means of enhancing driver safety on the roads. The successful integration of YOLOv5 with Arduino demonstrates the potential for deploying sophisticated deep learning models in real-world applications, paving the way for improved road safety worldwide.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

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