HELMET DETECTION USING MACHINE LEARNING

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Abstract—Helmet non-compliance among two-wheeler riders is a significant road safety concern, leading to numerous accidents, severe injuries, and fatalities. Traditional enforcement methods relying on manual monitoring are inefficient, labor-intensive, and prone to errors, necessitating an automated solution. This project introduces a real-time helmet detection system using YOLOv5, a deep learning-based object detection model known for its high accuracy and fast processing capabilities.

Developed using Python, OpenCV, and PyTorch, the system processes live video feeds and static images to detect whether a rider is wearing a helmet. A well- structured dataset containing labeled images of helmeted and non-helmeted riders was used for training, with the model fine-tuned to ensure high detection accuracy across various lighting and environmental conditions. Implemented on a computer with GPU acceleration, the system achieves real-time performance with minimal latency. Evaluation metrics such as precision, recall, and mean Average Precision (mAP) validate its reliability and effectiveness. The proposed system can be integrated with traffic surveillance, automated fine collection systems, and smart city infrastructures to enhance helmet law enforcement and road safety. Future enhancements may include license plate recognition, cloud-based data storage, and IoT-based realtime alerts, further strengthening automated compliance monitoring and reducing human intervention in traffic law enforcement.

Index Terms—ESP32 Camera, Raspberry Pi, Arduino Board (Mega), Camera (Dashboard-mounted), Motorcycle Ignition System, User Notification System

I. INTRODUCTION

Ensuring road safety for motorcyclists remains a critical concern, especially in urban environments where two-wheeler usage is high. One of the most effective safety measures is the mandatory use of helmets, yet enforcement remains a challenge. To address this, a real-time helmet detection system is proposed that uses a blend of machine learning and embedded systems to automatically verify whether a rider is wearing a helmet before the motorcycle can start. The system integrates an ESP32 camera module to capture live images of the rider and a Raspberry Pi for processing the images using deep learning algorithms. A Convolutional Neural Network (CNN), possibly based on MobileNet, is employed to detect the presence of a helmet. Upon successful detection, the Raspberry Pi sends a signal to an Arduino board which then allows the motorcycle ignition system to engage. In the absence of a helmet, the bike remains inoperative and notifies the rider via visual or auditory alerts.

This approach not only enhances rider safety but also automates compliance, reducing reliance on manual enforcement. The system is designed to be robust, functioning under various environmental conditions including low-light, occlusion, and motion blur. It showcases a practical use of machine learning in embedded hardware, with potential for wide adoption in the automotive industry to help reduce accident fatalities and promote responsible riding behavior.

II. LITERATUREREVIEW

Several approaches have been proposed related to this issue in many papers.Of these,some specific pa- pers have been analyzed in the following paragraphs. Godbole, T., Sapkal, P., Malapure, S., and Ganbavale, S.[2] presents a

system designed to enhance road safety by automatically detecting whether a motor- cyclist is wearing a helmet. Using machine learning techniques and computer vision tools sucha s Open CV, the system processes real-time video feeds or images to identify the presence of helmets.Krishnan, H. R., Ilamchezian, J., and Sarala Devi, V.[3] presents an automated system aimed at improving road safety by detecting motorcyclists not wearing helmets and issu- ing electronic challans. Suma, S., G L, A., and B N, M[6]introduces an automated helmet detection system aimed at enhancing road safety for two-wheeler riders in India. The authors employ the advanced YOLOv8 algorithm, utilizing the Ultralytics implementation, to achieve real-time object detection with high accuracy. Seemi, S. F., and Singh, G.[4] presents an automated system designed to enhance road safety by detecting two specific traffic violations: helmetless riding and triple riding on motor cycles. Agorku, G., Agbobli, D., Chowdhury, V., Amankwah-Nkyi, K., Lartey, P. A., Ogungbire, A., Aboah, A.[1]presents an automated system designed to enhance road safety by detecting helmet violations among motorcyclists. The system employs the YOLOv5 deep learning model to identify riders and passengers on motorcycles and determine whetherrthey are wearing helmets. Srusti, C.,Deo, V., and Jaiswal, R. C.[5]presents an automated system aimed at enhancing road safety by detecting motorcycl is ts not wearing helmets. The authors utilize machine learning techniques, specifically a cascade classifier based on HAAR features, to identify helmetless riders in real-time video feeds.

III. SYSTEMCOMPONENTS
A. Block Diagram
The system starts with an ESP32 Camera capturing the rider's image. This image is sent to the Raspberry Pi for processing. The Raspberry Pi runs a machine learning model to detect helmet usage. If a helmet is detected, it signals the Arduino Mega. The Arduino then enables the motorcycle ignition system. If not, it keeps the ignition off and activates a buzzer or LEDto alert the rider.
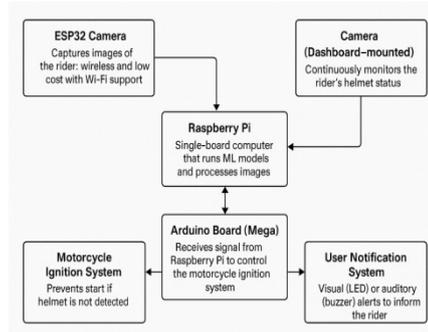

Figure1:System Block Diagram

B. System Architecture
This system starts with the ESP32 Camera capturing rider images and sending them to the Raspberry Pi. The Pi runs a helmet detection model and sends the result to the Arduino Mega. If no helmet is detected, the Arduino blocks ignition and triggers a buzzer or LED alert. Optional modules like SD card and cloud sync add data logging and remote monitoring features.
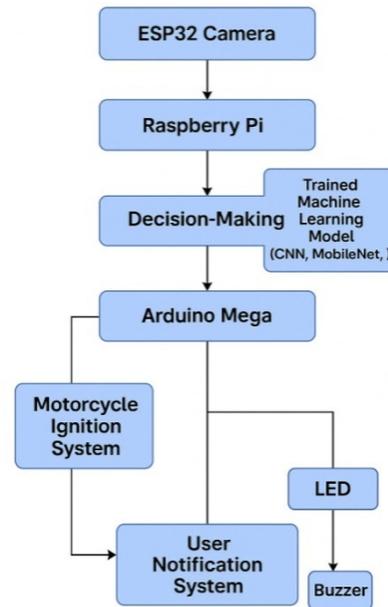

Figure 2:RASPBERRY PI

C. RaspberryPi5
The Raspberry Pi5, releasedin 2023, featuresa 2.0 GHz quad-core ARM Cortex-A76 CPU and a Video Core VII GPU, offering significant performance improvements over previous models. It comes with 8GB of LPDDR4 RAM, USB 3.0 ports, Gigabit Ethernet, and dual HDMI 2.1 outputs supporting 4K displays.It is the main processing unit responsible for running

the code, interfacing with sensors and managing communiction modules.

Figure3: RASPBERRY PI

D. Buzzer

The buzzer is used as an auditory alert system in the helmet detection project. It sounds when the system fails to detect a helmet on the rider. This immediate feedback helps ensure the rider is aware of the issue. It enhances safety by preventing the bike from starting without helmet use.

Figure4: BUZZER

IV. ADVANTAGES

• Enhanced Rider Safety – Prevents motorcycles from starting unless a helmet is detected, sig- nificantly reducing the risk of head injuries in accidents.

• Real-Time Operation – Real-Time Operation Processes images instantly using Raspberry Pi and ESP32 camera to detect helmet presence in real-time.

• Automation of Enforcement – Eliminates the need for human intervention or external monitor- ing to ensure helmet usage.

• Compact and Cost – Effective Design Utilizes low-cost components like ESP32 and Raspberry Pi, making it affordable and accessible for mass adoption.

• Adaptability to Various Environments – De- signed to operate under different lighting con- ditions, motion blur, and complex backgrounds, making it reliable in real-world traffic scenarios.

• High Detection Accuracy – Employs CNN- based models like MobileNet, known for bal- ancing speed and accuracy, even with small or partially occluded helmet images.

• Easy Integration with Existing Systems – Can be smoothly integrated with the motorcycle's ignition circuit usinga n Arduino board for seamless control.

• User Feedback Mechanism– Visualorauditory alerts notify the rider if a helmet is not detected, ensuring clear communication.

• Scalable for Large-Scale Deployment – With its lightweight architecture and open-source tools (like OpenCV, Tensor Flow), the system can be scaled across fleets or usedin traffic surveillance.

V. APPLICATIONS

• Motor cycle Ignition Control– Preventsthebike from starting unless a helmet is worn, enhancing rider safety.

• Traffic Rule Enforcement – Can be used by traffic authorities to monitor helmet compliance automatically.

• Fleet Safety Management – Useful for delivery or logistics companies to ensure employees wear helmets before riding.

• Smart Vehicle Systems–Can be integrated into smart bikes as a safety feature in next-gen vehicles.

• Public Awareness Campaigns – Demonstrates the importance of helmet usage in safety education and awareness programs.

• Urban Surveillance Systems–Can be integrated into traffic cameras for detecting helmet usage in busy city areas.

VI. RESULTS AND DISCUSSION

The implementation of the helmet detection system produced highly encouraging results, demonstrating the feasibility and effectiveness of using machine learning and embedded systems for enhancing road safety. The ESP32 Camera successfully captured real- time images of the rider, and theRaspberryPi,running a trained helmet detection model, accurately analyzed these images to determine helmet usage. The Arduino Mega responded promptly to the detection results by either enabling or disabling the motorcycle's ignition system. During testing, the system showed high accuracy in recognizing whether the rider was wearing a helmet across various conditions, including different helmet styles, colors, and environmental lighting. It consistently

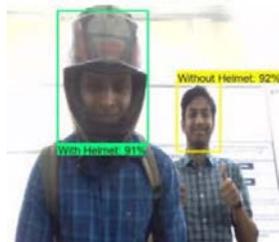prevented the motorcycle from starting when no helmet was detected and provided immediate feedback through a buzzer or LED alert.

Figure5:Result

The system's performance was reliable under nor- mal lighting and stationary conditions, although minor challenges were observed in low-light environments and when helmets were partially occluded or tilted at extreme angles. Despite these limitations, the model handled most real-world scenarios effectively. The modular design also allowed for easy testing and integration of each component. These results support the viability of the system for real-time deployment, and its cost-effective architecture makes it suitable for widespread use. With additional refinements, such as improved image processing and environmental adapt- ability, the system can serve as a valuable safety mechanism to promote responsible riding and reduce helmet-related traffic violations.

VII. CONCLUSION

The proposed helmet detection system effectively enhances rider safety by ensuring that a motorcycle can only be started when the rider is wearing a hel- met. By integrating machine learning with embedded systems like the Raspberry Pi, ESP32 Camera, and Arduino Mega, the system offers real-time, automated monitoring without human intervention. Its ability to operate under varied conditions and alert the rider when a helmet is not detected makes it both practical and scalable. This solution not only promotes responsible riding behavior but also has the potential for wide spread implementation in the auto motive industry to reduce accident-related fatalities.

VIII. FUTUREENHANCEMENT

In the future, the helmet detection system can be enhanced with several advanced features to increase its functionality and usability. Integrating a mobile application can providereal-time alerts, statusupdates, and system logs directly to the user or concerned authorities. Cloud connectivity can enable secure data storage and remote monitoring of helmet usage pat- terns. Adding GPS tracking will help monitor location- based behavior, while facial recognition can identify individual riders and ensure accountability. The sys- tem can also be extended to include an emergency alert mechanism that automatically notifies contactsor emergency services in case of an accident. To improve performance in low-light conditions, infrared or night vision cameras can be incorporated. Addi- tionally, adopting solar-powered operation can make the system more sustainable and suitable for long-term deployment in diverse environments.

REFERENCES

[1]   Agbobli D. Chowdhury V. Amankwah-Nkyi K. Lartey P. A. Ogungbire A. Aboah A Agorku, G. Real-time helmet violation detection using yolov5 and ensemble learning.2023.

[2]   Sapkal P. Malapure S. Ganbavale-S. (2024) God- bole, T. Helmet detection using machine learning andopencv..InternationalJournalofResearchin Engineering, Science and Technology (IJREST)., 2024.

[3]   Ilamchezian J. Sarala Devi-V Krishnan, H. R. Enhancing road safety with real-time helmet de- tection and challan issuance using yolo and ocr. International Research Journal of Modern Engi- neering and Technology (IRJMET)., 2024.

[4]   Singh G Seemi, S. F. Triple riding and helmet de- tection using deep learning. Journal of Emerging Sciences, 2023.

[5]   Deo V. Jaiswal R. C Srusti, C.Helmet detection using machine learning.pages 1–5, 2022.

[6]   G L A. B N-M Suma, S. Helmet detection based on improved yolo v8.2024.