DESAUTELS Faculty of Management
Faculté de gestion

MGSC 673

Introduction to AI and Deep Learning

Group Project

Automated Detection of Helmet Compliance Among Motorcyclists in India Using Deep Learning

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Executive Summary

Road traffic injuries are currently recognized as the eighth leading cause of death worldwide across all age groups and are expected to rise to the seventh leading cause by 2030 [1, 2]. Each year, road traffic crashes result in approximately 1.35 million fatalities and 50 million non-fatal injuries globally [1, 2].
Motorcyclists account for one-fourth of all road traffic-related deaths [2]. In high-income countries, motorcycle fatalities make up around 12% of total road traffic deaths, whereas in middle-income countries, this percentage increases to 26%. In the South-East Asian region, this figure stands at 34% [2]. In India, motorcycle riders contribute to 34–71% of all traffic accident fatalities [3].
Head injuries are a major cause of mortality among motorcyclists, comprising 88% of motorcycle-related deaths in low- and middle-income countries [4]. Helmet usage significantly enhances safety by reducing the risk of head injuries by 69% and the likelihood of death by 42% [5].

Using advanced deep learning techniques such as YOLO and Faster R-CNN, our system first detects motorcycles in video footage or images captured from Indian streets. Once detected, the system classifies riders into two categories: **With Helmet** and **Without Helmet**. To further enhance enforcement and monitoring, Optical Character Recognition (OCR) algorithms are employed in the cases where the person wear not wearing a helmet to identify and extract the motorcycle's license plate number, enabling efficient tracking of non-compliant riders.

Model Performance

Yolo model trained on 120 Epochs and had a early stop due to lack of further improvement. The model performs well overall, with an mAP50 of 85.8%.

"Without Helmet" class has higher recall (0.932) than the "With Helmet" class (0.777), meaning the model is better at identifying helmet absences than detections.

The system misclassifying compliant riders as not wearing a helmet is a critical issue, so we should also focus on minimizing false positives in the "Without Helmet" class (Or increasing Box(P)). Our model needs improvement to ensure better precision while maintaining high recall.

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Model summary (fused): 112 layers, 43,608,150 parameters, 0 gradients, 164.8 GFLOPs
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100% 5/5 [00:04<00:00,  1.24it/s]
                   all        133        228      0.764      0.777      0.794      0.508
           With Helmet        100        162      0.839      0.932      0.901       0.59
        Without Helmet         40         66      0.689      0.621      0.687      0.425
Speed: 0.2ms preprocess, 23.2ms inference, 0.0ms loss, 2.1ms postprocess per image
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Dataset Used

1. Helmet Detection from Roboflow [Link]
   629 images for computer vision project, with two classes: With Hemlet, Without Helmet
2. Helmet Detection Dataset from Kaggle [Link]
   This dataset contains 764 images of 2 distinct classes for the objective of helmet detection. Bounding box annotations are provided in the PASCAL VOC format

Models Used

YOLOv8 Large was the best performing model

We chose YOLOv8 Large because it is a suitable balance between accuracy and speed for helmet detection in complex scenes without overwhelming the GPU. We applied an image size of 640 because it is enough for accurate detection without using more memory than larger sizes. We also chose a batch size of 16 to offer stable training without memory overflow. To speed up training and optimize it, we enabled Automatic Mixed Precision (AMP), which reduces memory usage by utilizing half-precision computation wherever feasible.

We used a series of data augmentations like mosaic, mixup, color correction, flip, scale, and rotate to enhance the robustness of the model across different lighting and environmental conditions. This trains the model to identify helmets even in low light, blurred, or noisy video. We also set a confidence threshold of 0.4 to reduce false positives, ensuring that only high-confidence detections are considered. An IOU threshold of 0.65 was used to improve precision by reducing overlapping boxes. Also, there are parameters like perspective that can be changed for better capturing subjects from different angles. These settings help the model perform reliably in real-world scenarios, like crowded or low-quality video feeds.

Ethical Consideration Questions

1. **Real-World Applications**
o What are the practical applications of your chosen model or system?
This technology has several direct applications in traffic-related scenarios, including:

- Traffic Law Enforcement: Assisting authorities in monitoring and penalizing riders who violate helmet laws, ensuring compliance with safety regulations.
- Road Safety Initiatives: Supporting government and non-government campaigns to promote helmet use, aiming to reduce head injury-related fatalities and improve overall road safety.
- Traffic Surveillance: Integrating with CCTV networks and automated traffic management systems to detect violations in real time and improve public safety measures.
- Smart City Management: Integrated into urban surveillance systems, this technology can help monitor traffic patterns, enforce safety regulations, and assist in accident investigations.

By leveraging computer vision and deep learning techniques, our model aims to enhance road safety enforcement, promote responsible riding behavior, and contribute to a safer urban mobility environment.

o How can it be used in different industries or societal contexts?

- Crime Prevention & Investigation: Law enforcement can track motorcycles or vehicles involved in crimes by identifying license plates and cross-referencing them with police databases.
- Insurance & Risk Assessment: Insurance companies can leverage this system to assess risk profiles, detect risk factors associated with helmet usage and process claims more efficiently.
- Workplace & Delivery Services: Companies relying on motorcycle-based logistics, such as food delivery or courier services, can ensure their employees adhere to safety standards, reducing accidents and liability.

2. **Ethical Considerations in Development and Evaluation**

o What ethical factors should be considered when designing and testing this system?

Developing and evaluating a deep learning system for helmet and license plate detection is associated with several ethical considerations:

- Privacy and Data Protection: The system processes video footage and images, which may include personal data such as faces, license plates, and other identifying information. While improving road safety is the primary goal, the system should not lead to excessive surveillance.
  Solution: Implement strong encryption, access controls, and anonymization techniques (e.g., blurring faces) to protect user privacy.

- Transparency and Accountability: Authorities and stakeholders using the system for decision-making must be aware of its limitations, including false positives and false negatives.
  Solution: Ensure explainability in AI decisions and report error rates, and bias assessments.

- Informed Consent and Public Awareness: If used in public spaces, the public should be informed about the presence of surveillance technology, its purpose, and how data is handled.
  Solution: Governments and organizations should provide public notices, and accessible documentation outlining how long the data is stored, and how individuals can challenge errors.

3. **Potential Risks and Consequences**

o What are the possible failures or misuses of this system?

- Misuse for Mass Surveillance: If not properly secured, footage or data extracted by the system could be misused for tracking individuals beyond its intended purpose. A system designed for road safety could be repurposed for large-scale public surveillance, raising concerns about civil liberties and individual freedoms.
- Risk of Governmental Overreach: The system collects civilian data, including license plates and facial features. If widely deployed, such as across streets in India, governmental offices could use

this technology for identification, tracking, or social monitoring. This kind of system can be used with bad intentions. For example, suppose people protest peacefully for their human rights or participate in public demonstrations—this technology could be used to identify individuals against their will, leading to potential suppression and human rights violations.

o What could be the social, legal, or personal consequences if the model makes mistakes or is misused?

- Privacy Violations: Unauthorized access, misuse of surveillance, or lack of sufficient data security could lead to privacy breaches on a larger scale.
- Model Error: False negatives and false positives could lead to wrongful penalties or unnecessary legal complications, reducing the system's effectiveness in enforcing safety regulations. Data biases or issues with training data may result in false detection. Cases such as different types and brands of motorcycles or helmets, long hair, or hijabs worn by women could lead to errors.
- Disproportionate Penalties: Over-reliance on automated systems without human oversight might result in unfair penalties.
- Public Resistance: Excessive monitoring might be perceived as intrusive, and if the model incorrectly identifies riders, it could lead to legal disputes, public resistance, and debates over ethical surveillance.

4. **Legal and Ethical Safeguards**

o What laws, policies, or guidelines should be in place to prevent misuse or harmful outcomes?

- Privacy Laws: Data collection should comply with international privacy laws such as GDPR (General Data Protection Regulation - EU) and India's Data Protection Bill (if applicable).
- Data Storage Policies: Data storage should be minimized, ensuring that the system stores only necessary information and deletes data after a legally defined period.
- Regular AI Audits: Conduct external AI audits to ensure the system is free from racial, gender, and socioeconomic biases. Additionally, verify that helmet detection accuracy remains consistent across different demographic groups.
- Explainability & Human Oversight (Explainable AI): AI decisions should be interpretable and explainable, allowing developers, legal bodies, and affected individuals to detect and correct errors when necessary.
- Diversity in Training Data: The model should be trained on diverse datasets that include different genders, ethnicities, helmet colors, varied weather and lighting conditions, and various motorcycle models to ensure fair and accurate detection.

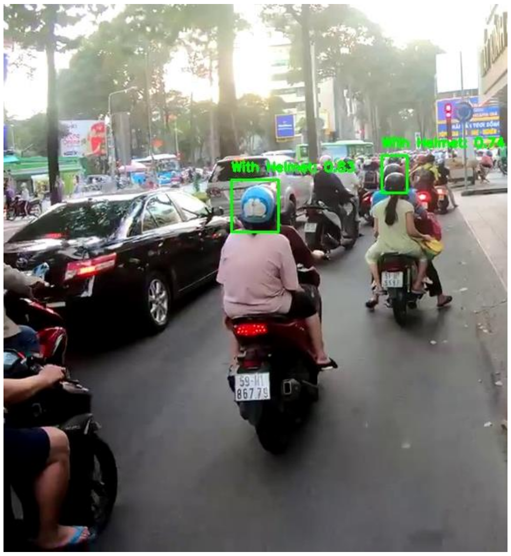
o How can we hold developers and organizations accountable for the ethical deployment of this system?

- Transparency Reports & Public Scrutiny: Organizations must publish regular AI fairness reports detailing false positive rates, system accuracy, and bias mitigation efforts.

- Independent Oversight Committees: AI ethics boards should monitor and approve system deployment, including civil rights groups, legal experts, and AI specialists.
- Allow Public & Legal Appeals: If a rider is wrongly penalized, they should have legal channels to challenge and dispute the decision. Implement an automated appeal system where riders can submit evidence (e.g., helmet footage).

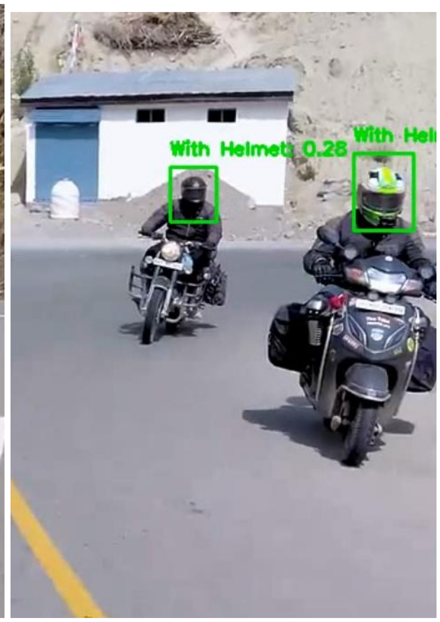
Appendix: Model Outputs

- Images as Inputs_With Helmet



- Images as Inputs_Without Helme

- Videos as Inputs_With Helmet



- Videos as Inputs_Without Helmet

Resources:

1.Global status report on road safety 2018. Geneva: World Health Organization 2018. https://www.who.int/publications-detail/global-status-report-on-road-safety-2018

2.Global status report on road safety 2015. Geneva: World Health Organization 2015. www.who.int/violence_injury_prevention/road_safety_status/2015/en

3.Gururaj G, Gautham MS. Advancing road safety in India-implementation is the key. Bengaluru: National Institute of Mental Health & Neuro Sciences; 2017. [Google Scholar]

4.Helmets: a road safety manual for decision-makers and practitioners. Geneva: World Health Organization 2006. https://www.who.int/publications-detail/helmets-a-road-safety-manual-for-decision-makers-and-practitioners

5.Liu BC, Ivers R, Norton R, et al. Helmets for preventing injury in motorcycle riders. Cochrane Database Syst Rev. 2008:CD004333. 10.1002/14651858.CD004333.pub3.

6.Setty, Naveen Kikkeri Hanumantha, et al. "Prevalence and Factors Associated with Effective Helmet Use among Motorcyclists in Mysuru City of Southern India." *Environmental Health and Preventive Medicine*, vol. 25, 2020, Article 47, https://doi.org/10.1186/s12199-020-00888-z.