Accredited SINTA 2 Ranking
Decree of the Director General of Higher Education, Research, and Technology, No. 158/E/KPT/2021
Validity period from Volume 5 Number 2 of 2021 to Volume 10 Number 1 of 2026

Published online at: **http://jurnal.iaii.or.id**

JURNAL RESTI
(Rekayasa Sistem dan Teknologi Informasi)
Vol. 8 No. 3 (2024) 355 - 360 e-ISSN: 2580-0760

Convolutional Neural Network and LSTM for Seat Belt Detection in Vehicles using YOLO3

Erika Devi Udayanti[1], Etika Kartikadarma[2], Fahri Firdausillah[3]
[1,2,3]Faculty of Computer Science, Universitas Dian Nuswantoro, Semarang, Indonesia
[1]erikadevi@dsn.dinus.ac.id, [2]etika.kartikadarma@dsn.dinus.ac.id, [3]fahri.firdausillah@dsn.dinus.ac.id

Abstract

The application of an electronic violation detection system has begun to be implemented in many countries by utilizing CCTV cameras installed at highway and toll road points. However, the development of a violation detection system using data in the form of images that have a high level of accuracy is still a challenge for researchers. Several types of violations detected include the use of seat belts and the use of cell phones while driving which is influenced by the number of vehicles, vehicle speed and lighting which can increase the difficulty in the detection process. This research developed a traffic violation detection system using YOLO3. The YOLO is used as the basic architecture of CNN which is then combined with LSTM. The dataset was obtained from RoboFlow Universe with a total of 199 front-view car images consisting of 82 using seatbelts and 78 not using seatbelts for the training process. The CNN algorithm plays a role in the feature extraction process from input image data, while LSTM plays a role in the prediction process. Furthermore, the performance evaluation of the CNN+LSTM algorithm will be measured using the value of accuracy to measure the performance of the training process and testing process. In measuring the performance of the training process, it will be compared with several basic detection models used, such as CNN, VGG16, ResNet50, MobileNetV2, YOLO3, and YOLO3+LSTM. The test results show that YOLO3+LSTM has higher accuracy compared to the others at 89%. Next, in the testing process, the CNN+LSTM model will be compared with the basic method, namely CNN. The test results show that the CNN+LSTM models have higher accuracy at 89%. Meanwhile, in the basic CNN model, the resulting accuracy was 85%.

Keywords: *intelligent systems; seat belt violation detection; yolo; convolutional neural networks, LSTM*

How to Cite: E. Udayanti, Etika Kartikadarma, and Fahri Firdausillah, "Convolutional Neural Network and LSTM for Seat Belt Detection in Vehicles using YOLO3", *J. RESTI (Rekayasa Sist. Teknol. Inf.)*, vol. 8, no. 3, pp. 355 - 360, Jun. 2024.
DOI: https://doi.org/10.29207/resti.v8i3.5784

1. Introduction

The problem of traffic violations has become a serious concern nowadays, along with the high volume of traffic due to the increasing number of cars and other vehicles [1], [2]. The increase in the number of accidents that occur as a result of violations of traffic rules is very important to control. In general, traffic violations such as breaking a red light, not wearing a helmet, not using a seat belt and violating traffic markings. Enforcement of traffic regulations through manual ticketing has begun to be abolished as a form of effort to increase police professionalism. One of the government's efforts that has recently been implemented is the use of electronic traffic tickets or ETLE (Electronic Traffic Law Enforcement) [3], [4]. ETLE is a new method of applying traffic discipline used by police officers to detect traffic violations. The use of ETLE can be installed on police vehicles so that it is more flexible.

Figure 1. Mobile dan static ETLE

Furthermore, static ETLE is implemented using CCTV cameras placed at certain points on protocol roads as shown in Figure 1. ETLE technology is a violation detection system that is increasingly being implemented in Indonesia using data in the form of images. However, this system is a challenge for researchers considering

Received: 26-04-2024 | Accepted: 23-05-2024 | Published Online: 04-06-2024

the number of vehicles, vehicle speed and lighting which are obstacles in the detection process.

Image-based traffic violation detection systems relate to image processing, Artificial Intelligence and deep learning which are used to detect objects and their classification classes in the form of images and videos[5]–[13]. With the increasing rate of traffic casualties, especially among car drivers, enforcing regulations on the use of seat belts has become very important to effectively protect driver safety. For this reason, in this research, the development of a traffic violation detection system is focused on detecting the object of seat belt use in car drivers.

Several studies have been carried out in the development of a traffic violation detection system. Researchers Kashevnik [5] developed a system for detecting seat belts in vehicle cabins and monitoring driver behaviour [14] using the YOLO method. However, this detection system still has to consider reducing parameters and improving performance.

Researcher Ravish [10] developed a system for detecting traffic violations such as violating red traffic signals, not using a helmet and not using a seat belt using the YOLO method. After all, traffic violations can only be detected during the day. Franklin researchers [11] developed a detection system for traffic violations such as vehicle speed, traffic signals and number of vehicles using the YOLO method. However, further development is still needed to reduce the computation time in high road traffic volumes.

Researcher Chun[15] developed seat belt detection and driver and passenger behaviour using the NADS-Net architecture on the CNN algorithm with cameras and infrared light in the vehicle cabin. However, this method is susceptible to data collection bias. Researcher Yang[16] developed a seat belt detector using a deep learning algorithm with the MobileNet V2 architecture by paying attention to the accuracy of using the belt. Furthermore, researcher Yi [17] detects the correct use of seat belts using the Part Affinity Field (PAF) algorithm. The use of cameras placed in the vehicle cabin. To identify whether the driver is wearing the seat belt correctly based on human joint points.

Several studies related to the development of a traffic violation detection system have been described. Table 1 summarizes the methods used in previous studies.

In this research, the detection model developed is limited to car drivers and will be further developed to detect belt use in front of passengers. The YOLO model is used to detect the use of seat belts on drivers and the classifier model uses CNN+LSTM with hyperparameter settings to obtain higher accuracy than another method. Furthermore, the performance evaluation of the algorithm will be measured using the RMSE value and compared with several basic detection models used, such as CNN, VGG16, ResNet50, MobileNetV2, Yolo3, Yolo3 and CNN+LSTM.

Table 1. Research related to traffic violation detection systems

Application Detection	Method	References
Seat belt tightness Driver behaviour monitoring	Camera in the car cabin YOLO	[5], [14]
Traffic red signal violation Not wearing a helmet Not using a seat belt	Static camera YOLO	[10], [18]
Vehicle Speed, Violating traffic signals Number of vehicles	Static camera YOLO	[11], [19], [20]
Seatbelt Driver and passenger behaviour	Camera in the car cabin NADS-Net	[15], [21]
Safety belt	Static camera MobileNet V2 and the Particle Filter algorithm	[16]
Correct use of seat belts	Camera in the car cabin Part Affinity Field (PAF)	[17]
Use of seat belts for drivers	Dataset from static Camera YOLO with modified CNN +LSTM hyperparameters	Propose Method

2. Research Methods

This research develops a violation detection system for using seat belts through static cameras using YOLO and the CNN+LSTM algorithm. Based on Figure 2, image data is taken through CCTV cameras placed on the road and the vehicle detection module will take pictures of the cars that pass through it. Next, the windshield detection module will determine the position of the car's windshield.

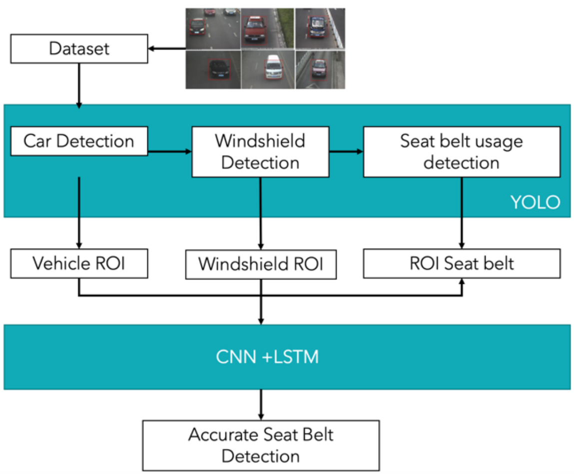

Figure 2. CNN-LSTM-based seat belt use detection system

After that, the seat belt detection module will determine the position of the driver and detect seat belt use. CNN and LSTM algorithms are used for the violation classification process by detecting seat belt use. This research will further develop the CNN and LSTM algorithm hybrid models with hyperparameter settings to obtain high accuracy. Next, the performance evaluation of the CNN algorithm will be measured using the RMSE value and compared with other algorithms.

Research begins by first identifying needs, namely determining the components in developing a prototype of an intelligent system for detecting driving violations in the use of seat belts. Furthermore, the development of the model is carried out starting from the process of detecting the seat belt object obtained from the RGB image.

Next, develop a classification model to detect the use of seat belts. This detection process is first carried out in the pre-processing stage, namely noise removal and normalization of raw data. After pre-processing, it is continued with the feature extraction stage. At this stage, the features will be obtained which will be used in the detection process of seat belt usage.

The next process is to develop a CNN method with modifications and adjustments to the hyperparameters for the seat belt use detection process. The next stage is an assessment of existing conditions and then determining the development of an appropriate model, which aims to carry out data analysis. From this model, a prototype model was developed in the laboratory based on the system that had been designed. Furthermore, efforts are also made to optimize the performance of the system that has been built.

This study uses the YOLO method to detect the use of seat belts on 4-wheeled vehicles through static cameras. The YOLO method was developed by modifying the CNN algorithm in combination with LSTM and hyperparameter settings. The process of detecting seat belt use is carried out through an image processing process with several stages as shown in Figure 3.

Data in the form of images/videos is taken using RGB cameras that are installed statically at several points on roads that are busy with vehicles. Data was taken from several places and in different weather, namely morning, afternoon, cloudy conditions and rainy conditions.

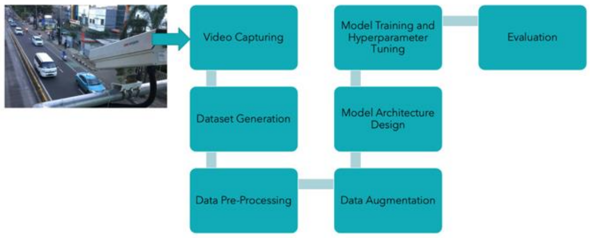

Figure 3. The process of detecting a violation of the use of seat belts

The data that has been recorded is then prepared to be used as a dataset. The data covers different types of vehicles, namely large, medium and small. The dataset created is estimated to consist of 100 images for initial research.

At data pre-processing stage, the images are processed in such a way that they are suitable for model training. Some of the methods used in image pre-processing include: Cropping image: cropping the image so that only the front view of the driver is visible; Resizing image: resizing the image to 128 x 128; Blurring image: blurring the image for smoothness using the Gaussian method; The pre-processing method can be performed using the pre-process_input() function from the Keras library.

CNN is used as a classification model to determine violations of seat belt use. The YOLO method is used as the basic architecture of CNN which is then combined with LSTM. Figure 4 shows the YOLO architecture with a combination of the CNN and LSTM algorithms. In the initial implementation, the parameter values in the CNN are determined as in Figure 5. Image processing and analysis are performed using a single image object. The object analysis process is aimed at objects on the windshield with various image angles. The image analysis model is a CNN model which consists of input layers, convolution layers, LSTM layers and then connected into one fully connected layer. The extraction process occurs on the image object in the windshield area of the car.

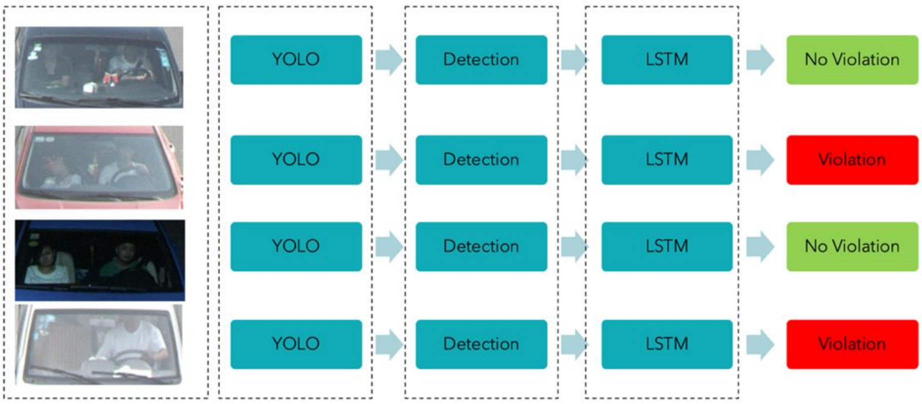

Figure 4. YOLO model architecture (CNN+LSTM)

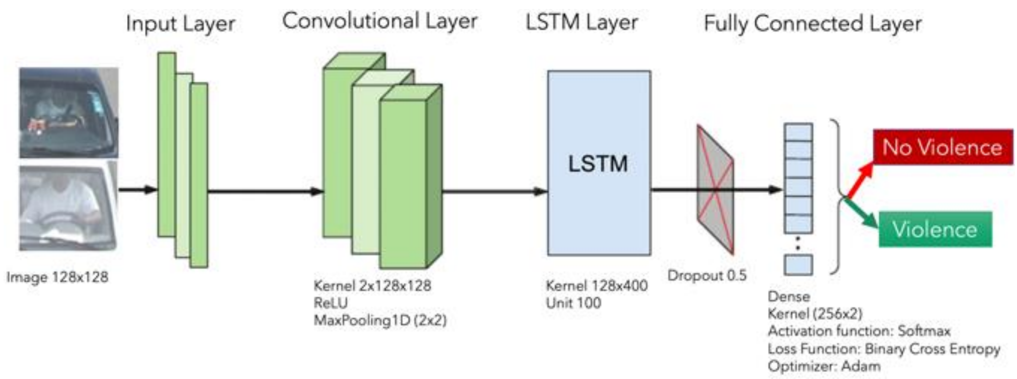

Figure 5. Layer Architecture on CNN+LSTM

To measure the performance of the classification algorithm, this research uses Accuracy to measure the performance of the training process and testing process. In measuring the performance of the training process, it will be compared with several basic detection models used, such as CNN, VGG16, ResNet50, MobileNetV2, Yolo3, Yolo3 and CNN+LSTM. Next, in the testing process, the proposed methods, namely CNN and LSTM, will be compared with the basic method, namely CNN.

3. Results and Discussions

The dataset was obtained from RoboFlow Universe in the form of 199 front-view car images. The dataset consists of images for the training process, namely 82 images using seatbelts and 78 images not using seatbelts.

Figure 6. The dataset with car drivers using seatbelt

Figure 7. The dataset with car drivers did not use a seatbelt

Figure 8. ROI area on car windshield with the driver wearing a seat belt

Figure 9. ROI area on the windshield of a car with the driver not wearing a seat belt

The validation process uses 40 images, namely 20 using a seatbelt and 20 images not using a seatbelt. The images provided are in bright lighting conditions and the driver is clearly visible. Figures 6 and 7 show several images in the dataset. The seat belt detection process uses the object of the car's windshield so that the driver's use of the seat belt can be analyzed.

The initial step in this detection is to first detect the presence of a vehicle and then take the Region of Interest (ROI) area on the car's windshield. Figures 8 and 9 show the car and car windshield objects which are the ROI area. The object detection results in this ROI are then classified into violation labels if you do not use a seat belt and do not violate if you use a seat belt.

The CNN model is used to classify violations and non-violations. The CNN model was chosen because it was proven to have good performance for classifying image objects, and there were many references available in image classification experiments. Furthermore, this study uses YOLO which is part of the CNN method.

YOLO as a classification model has high detection speed and accuracy. The YOLO model used in this research has good performance, compared to other basic CNN models in seat belt detection. Table 2 shows a comparison of accuracy in the training process.

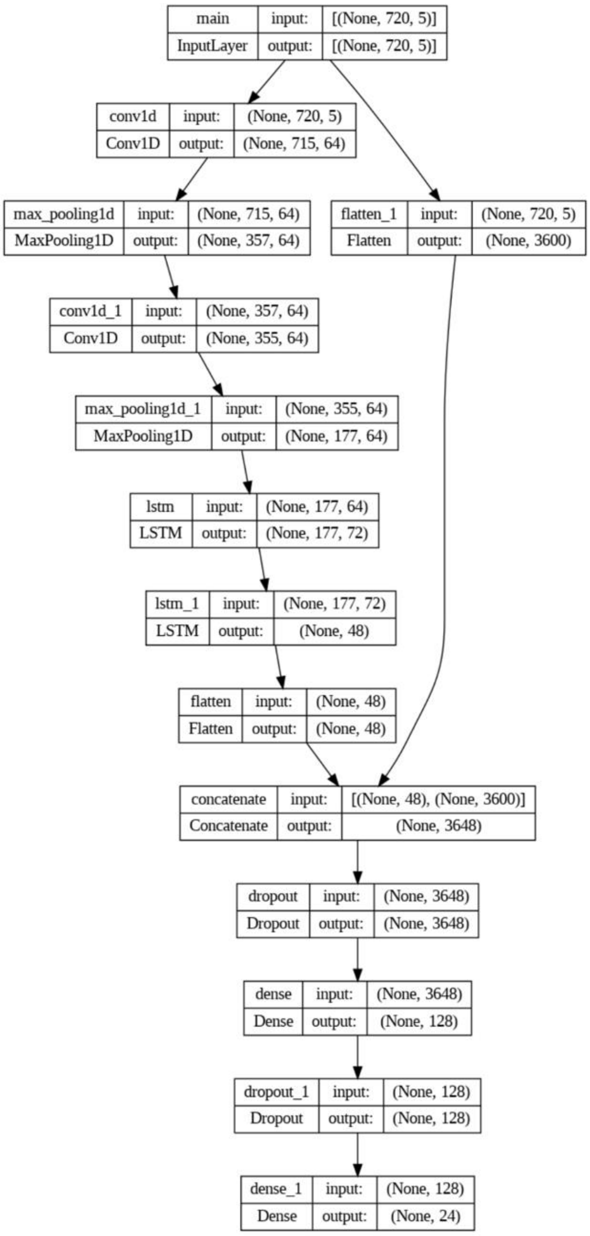

Figure 10. CNN + LSTM Model Architecture

Table 2. Comparison of accuracy in the training process of base models

Model Learning	Accuracy
CNN	85%
VGG16	80%
ResNet50	83%
MobileNetV2	85%
YOLO3	86%
YOLO3+LSTM	89%

In its application during experiments, the YOLO model architecture was adjusted to several parameter values and LSTM layers were used to increase classification accuracy. Several parameters in the architecture have been determined including the number of hidden layers, activation function, learning rate, epoch, batch size, optimizer, and loss function. The architectural model used in this research is shown in Figure 10.

The test results shown in Figure 11 that the Yolo and LSTM models have an accuracy of 89% which was carried out in experiments of 40 epochs and began to converge at the 4th epoch. Meanwhile, in the basic CNN model, the resulting accuracy was 85%.

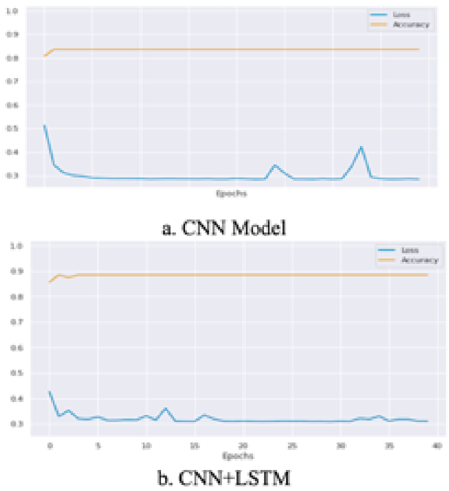

Figure 11. The test results of CNN + LSTM Model Architecture

This research has succeeded in testing the accuracy value of the CNN and LSTM models for detecting car drivers' seat belt use. Based on the state-of-the-art research, the results of this experiment have several advantages compared to research that has been conducted previously. Research [5], [14], [15], [17], [21] implemented a detection method using a camera in the car cabin, which has limitations in detecting only one car object. In research[10], [16] applied the use of static cameras and MobileNet v2 to detect several types of violations on many car objects, including the detection of seat belt use. However, such research requires high computation when the volume of detected objects increases. Therefore, the use of the YOLO model combined with LSTM in this research has produced high-accuracy results compared to other models, according to the results shown in Table 2 and Figure 11.

4. Conclusions

The application of the discipline of using a seat belt while driving is very important to be able to reduce the impact of an accident. With the increasing rate of traffic casualties, especially among car drivers, enforcing regulations on the use of seat belts has become very important to effectively protect driver safety. For this reason, in this research, the development of a traffic violation detection system is focused on detecting the object of seat belt use among car drivers. This study uses the YOLO model to detect objects and the hybrid model for classification using CNN and LSTM. The test results show that the Yolo and LSTM models have an accuracy of 89% which was carried out in experiments of 40 epochs and began to converge at the 4th epoch. Meanwhile, in the basic CNN model, the resulting accuracy was 85%.

Acknowledgements

This research was supported by Universitas Dian Nuswantoro and funded by Direktorat Riset, Teknologi, dan Pengabdian kepada Masyarakat (DRTPM) under the 2023 fundamental research grant scheme.

References

[1] A. C. P. Uy *et al.*, "Automated traffic violation apprehension system using genetic algorithm and artificial neural network," *IEEE Region 10 Annual International Conference, Proceedings/TENCON*, pp. 2094–2099, Feb. 2017, doi: 10.1109/TENCON.2016.7848395.

[2] E. M. Ben Laoula, O. Elfahim, M. El Midaoui, M. Youssfi, and O. Bouattane, "Traffic violations analysis: Identifying risky areas and common violations," *Heliyon*, vol. 9, no. 9, p. e19058, Sep. 2023, doi: 10.1016/J.HELIYON.2023.E19058.

[3] Y. Indarsih, "Application of Electronic Traffic Law Enforcement (E-TLE) Ticketing System Management at Polda West Java," *Enrichment: Journal of Management*, vol. 11, no. 2, 2021, [Online]. Available: www.enrichment.iocspublisher.org

[4] A. F. Rahmat and U. Pribadi, "Delivering Artificial Intelligence for Electronic Traffic Law Enforcement in Yogyakarta Region: Current Effort and Future Challenges," *IOP Conf Ser Earth Environ Sci*, vol. 717, no. 1, p. 012016, Mar. 2021, doi: 10.1088/1755-1315/717/1/012016.

[5] A. Kashevnik, A. Ali, I. Lashkov, and N. Shilov, "Seat Belt Fastness Detection Based on Image Analysis from Vehicle In-abin Camera," *Conference of Open Innovation Association, FRUCT*, vol. 2020-April, pp. 143–150, Apr. 2020, doi: 10.23919/FRUCT48808.2020.9087474.

[6] H. R. Mampilayil and K. Rahamathullah, "Deep learning based detection of one way traffic rule violation of three-wheeler vehicles," *2019 International Conference on Intelligent Computing and Control Systems, ICCS 2019*, pp. 1453–1457, May 2019, doi: 10.1109/ICCS45141.2019.9065638.

[7] X. Wang, L. M. Meng, B. Zhang, J. Lu, and K. L. Du, "A video-based traffic violation detection system," *Proceedings - 2013 International Conference on Mechatronic Sciences, Electric Engineering and Computer, MEC 2013*, pp. 1191–1194, 2013, doi: 10.1109/MEC.2013.6885246.

[8] "A video-based traffic violation detection system | IEEE Conference Publication | IEEE Xplore." Accessed: Mar. 27, 2023. [Online]. Available: https://ieeexplore.ieee.org/document/6885246

[9] A. C. P. Uy *et al.*, "Automated traffic violation apprehension system using genetic algorithm and artificial neural network," *IEEE Region 10 Annual International Conference, Proceedings/TENCON*, pp. 2094–2099, Feb. 2017, doi: 10.1109/TENCON.2016.7848395.

[10] R. Ravish, S. Rangaswamy, and K. Char, "Intelligent Traffic Violation Detection," in *2021 2nd Global Conference for Advancement in Technology (GCAT)*, IEEE, Oct. 2021, pp. 1–7. doi: 10.1109/GCAT52182.2021.9587520.

[11] R. J. Franklin and Mohana, "Traffic Signal Violation Detection using Artificial Intelligence and Deep Learning," in *2020 5th International Conference on Communication and Electronics Systems (ICCES)*, IEEE, Jun. 2020, pp. 839–844. doi: 10.1109/ICCES48766.2020.9137873.

[12] M. Gupta, H. Miglani, P. Deo, and A. Barhatte, "Real-time traffic control and monitoring," *e-Prime - Advances in Electrical Engineering, Electronics and Energy*, vol. 5, p. 100211, Sep. 2023, doi: 10.1016/J.PRIME.2023.100211.

[13] M. M. Rathore, A. Paul, S. Rho, M. Khan, S. Vimal, and S. A. Shah, "Smart traffic control: Identifying driving-violations using fog devices with vehicular cameras in smart cities," *Sustain Cities Soc*, vol. 71, p. 102986, Aug. 2021, doi: 10.1016/J.SCS.2021.102986.

[14] A. Kashevnik and A. Ali, "Comparison Platform Design for Neural Network Models Evaluation in Driver Monitoring Systems," in *2021 28th Conference of Open Innovations Association (FRUCT)*, IEEE, Jan. 2021, pp. 151–157. doi: 10.23919/FRUCT50888.2021.9347576.

[15] S. Chun *et al.*, "NADS-Net: A Nimble Architecture for Driver and Seat Belt Detection via Convolutional Neural Networks," in *2019 IEEE/CVF International Conference on Computer Vision Workshop (ICCVW)*, IEEE, Oct. 2019, pp. 2413–2421. doi: 10.1109/ICCVW.2019.00295.

[16] D. Yang, Y. Zang, and Q. Liu, "Study of Detection Method on Real-time and High Precision Driver Seatbelt," in *2020 Chinese Control And Decision Conference (CCDC)*, IEEE, Aug. 2020, pp. 79–86. doi: 10.1109/CCDC49329.2020.9164214.

[17] Q. Yi and Q. Yi, "Safety Belt Wearing Detection Algorithm Based on Human Joint Points," in *2021 IEEE International Conference on Consumer Electronics and Computer Engineering (ICCECE)*, IEEE, Jan. 2021, pp. 538–541. doi: 10.1109/ICCECE51280.2021.9342340.

[18] F. W. Siebert and H. Lin, "Detecting motorcycle helmet use with deep learning," *Accid Anal Prev*, vol. 134, p. 105319, Jan. 2020, doi: 10.1016/J.AAP.2019.105319.

[19] M. Famouri, Z. Azimifar, and A. Wong, "A Novel Motion Plane-Based Approach to Vehicle Speed Estimation," *IEEE Transactions on Intelligent Transportation Systems*, vol. 20, no. 4, pp. 1237–1246, Apr. 2019, doi: 10.1109/TITS.2018.2847224.

[20] M. Anandhalli, P. Baligar, S. S. Saraf, and P. Deepsir, "Image projection method for vehicle speed estimation model in video system," *Mach Vis Appl*, vol. 33, no. 1, p. 7, Jan. 2022, doi: 10.1007/s00138-021-01255-w.

[21] L. Nkuzo, M. Sibiya, and E. D. Markus, "A Comprehensive Analysis of Real-Time Car Safety Belt Detection Using the YOLOv7 Algorithm," *Algorithms*, vol. 16, no. 9, p. 400, Aug. 2023, doi: 10.3390/a16090400.

