









Fig. 2. Example of determining driver area.

The researcher combined multiple descriptors for improved accuracy. For example, Qin et al. used a combination of haar-like features and Histograms of Oriented Gradients (HOG) with Adaboost learning as a classifier [Qin et al., (2014)]. The test results on five video datasets showed that this combination yielded a better miss rate than only haar-like or HOG. Madake et al. employed Canny, FAST (Features from accelerated segment test), and BRIEF (Binary Robust Independent Elementary Features) for feature extraction [Madake et al., (2023)]. In addition, the research compared five classification methods, namely Decision Tree (DT), Support Vector Machine (SVM), Random Forest (RF), K-Nearest Neighbors (KNN), and Gaussian Naïve Bayes (GNB). The results showed that the proposed feature extraction combination achieved better accuracy compared to other methods such as Scale-Invariant Feature Transform (SIFT), Oriented FAST, and Rotated BRIEF (ORB) + FAST, ORB+FAST+Canny+Hough Transform, as well as FAST and BRIEF. It should be noted that the DT method exhibited the highest accuracy at 90.41%.

## 2.2. Non-handcrafted feature

Convolutional Neural Network (CNN) has recently emerged as the primary method for seat belt detection. Sajja et al. compared this method with SVM and found that CNN achieved superior accuracy [Naik et al., (2021)]. Kapdi et al. used the MobileNetV2 model, which showed robustness to various weather conditions [Kapdi et al., (2022)]. Additionally, Chen et al. combined CNN and SVM, using CNN for feature extraction and SVM for classification. This method, involving multi-scale feature extraction and applied to images with complex road backgrounds, outperformed the Adaboost algorithm and CNN regarding detection averages [Chen et al., (2018)]. Kannadaguli proposed a detection method with Fully Connected One Shot (FCOS) and added a prediction elimination process using Non-Maximum Suppression (NMS) [Kannadaguli, (2020)]. Meanwhile, Elihos et al. compared several models, including the single shot multi-box object detector (SSD), VGG16 model, shallor CNN model, and Fisher vector model, concluding that the SSD model achieved the highest accuracy [Elihos et al., (2019)].

Some research used YOLO (You Only Look Once) to detect the driver area. For example, Luo et al. employed YOLOv3 to detect the driver area and CNN for classification [Luo et al., (2021)]. The test showed that the proposed method achieved high accuracy and remained robust even in complex environments. Similarly, Wang and Ma also utilized YOLOv3 and a lightweight network structure [Wang and Ma, (2022)]. The test results showed that increasing the number of lightweight templates improved accuracy from 80.57% to 99.98%, but it slightly reduced the speed from 78 to 69 FPS. Khalid and Hazela used YOLOv4 to determine the driver area and the Alexnet model for classification [Khalid and Hazela, (2021)].

Meanwhile, Feng et al. proposed YOLOv5 for driver area detection and AlexNet deep convolutional network for classification [Feng et al., (2022)]. This method saved memory and computation time compared to SVM. In addition, compared with traditional CNN such as LeNet and AlexNet, the proposed method showed better performance in overfitting problems. Hosseini and Fathi used YOLOv5 for car windshield detection and the ResNet32 model for classification [Hosseini and Fathi, (2023)]. The research determined the driver and passenger areas by halving the windshield area. The test results showed that the proposed method achieved better accuracy than previous research, such as the connected area method, FCOS, and Alexnet model.

Maduri et al. proposed a real-time detection method for drivers not wearing a seat belt, which utilized deep learning and was embedded in Raspberry Pi [Maduri et al., (2021)]. Upadhyay et al. also focused on this

condition and applied the method in actual conditions using a camera installed in the cabin and YOLOv5 [Upadhyay et al., (2023)]. On the other hand, Zang et al. introduced the SlimSSDMV2 model and LSD (Line Segment Detector) for mobile devices [Zang et al., (2023)]. The proposed method produced 96.32% accuracy with a computation time of 358 ms.

Research also attempted to improve accuracy and speed by developing CNN models. Zhou et al. developed the Alexnet model by adding Batch Normalization (BN), producing BN-Alexnet [Zhou et al., (2017)]. The test results showed that this proposed method increased the average correct detection and reduced the training time compared to Alexnet, VGGNet-16, and GoogLeNet. Chun et al. proposed a CNN model named NADS-Net (A Nimble Architecture for Driver and Seat Belt Detection via Convolutional Neural Networks) using the feature pyramid network (FPN) backbone method and multiple detection heads [Chun et al., (2019)]. The method was applied under different demographics, appearances, and illumination. In addition, Yang et al. created a method that focused on CPU and real-time applications. The method combined traditional operators (texture extraction), SSD MobileNet V2, and the particle filter tracking algorithm. The test results showed that the proposed method improved precision [Yang et al., (2020)].

### 3. Result and discussion

The methods to locate the driver area, extract features, and classify data significantly impacted seat belt detection. It should be noted that previous research employed various handcrafted feature extraction methods. Combining these methods, such as Canny, FAST, and BRIEF [Madake et al., (2023)], showed improved accuracy. However, this led to increased computation time, which could be addressed by adding a feature selection process. This process involved a preprocessing technique for identifying key features, selecting relevant entities, and removing irrelevant and redundant ones [Remeseiro and Bolon-Canedo, (2019)]. Reducing the feature dimension enhanced performance, shortened training time, simplified the model, and sped up the classification process.

Several CNN models were widely used for seat belt detection, including SSD, VGG16, shallow CNN, and Fisher vector [Elihos et al., (2019)]. Among these models, SSD achieved the highest accuracy, and one of the CNN methods, namely Alexnet, was compared with the SVM classifier, which produced faster computation time.

YOLO for driver area detection produced high accuracy. Hence, various versions, such as YOLOv3, YOLOv4, and YOLOv5, were employed. Specifically, YOLOv5 showed better accuracy when compared to other methods, such as the connected area method, FCOS, and the Alexnet model [Hosseini and Fathi, (2023)]. Yung et al. compared YOLOv5, YOLOv6, and YOLOv7 to detect safety helmets [Yung et al., (2022)]. The test results showed that YOLOv7 achieved a better mAP than YOLOv5 and YOLOv6. In addition, YOLOv7 showed better accuracy and speed than the YOLOR, PP-YOLOE, YOLOX, Scaled-YOLOv4, and YOLOv5 algorithms. Therefore, it can be concluded that YOLOv7 has the potential to enhance seat belt detection by improving accuracy and speed.

### 4. Conclusions and future research

In conclusion, extensive research was done on detecting drivers not wearing seat belts. Some research has developed a system comprising car detection, windshield detection, and seat belt detection subsystems. However, the current research specifically focused on seat belt detection subsystems. When combining feature extraction methods with handcrafted features, accuracy tended to increase accuracy, but this also led to longer computation times. Therefore, a feature selection process could be implemented. Applying YOLOv5 to non-handcrafted features showed promising accuracy and speed, but further improvements were needed to make it suitable for real-time conditions. For enhanced accuracy, the implementation of YOLOv7 or YOLOv8 could be considered. Furthermore, recording data at the right angle and increasing image resolution can increase accuracy.

### Acknowledgments

The authors would like to thank the Ministry of Research and Higher Education of the Republic of Indonesia through Diponegoro University, which has funded this research with contract numbers 017/E5/PG.02.00.PL/2023.

### Conflict of interest

The authors have no conflicts of interest to declare.

## References

- [1] Arora, N. and Kumar, Y. (2022): Automatic vehicle detection system in day and night mode: challenges, applications and panoramic review. *Evolutionary Intelligence*, pp. 1077–95.
- [2] Berwo, M. A.; Khan, A.; Fang, Y.; Fahim, H.; Javaid, S.; Mahmood, J.; Abideen, Z. U.; and M.S. S. (2023): Deep learning techniques for vehicle detection and classification from images/videos: a survey. *Sensors*, **23**(10), pp. 1–35.
- [3] Chen, Y.; Tao, G.; Ren, H.; Lin, X.; and Zhang, L. (2018): Accurate seat belt detection in road surveillance images based on CNN and SVM. *Neurocomputing*, **274**, pp. 80–87.
- [4] Chun, S.; Ghalehjegh, N. H.; Choi, J.; Schwarz, C.; Gaspar, J.; McGehee, D.; and Baek, S. (2019): NADS-net: a nimble architecture for driver and seat belt detection via convolutional neural networks. in *17th IEEE/CVF International Conference on Computer Vision Workshop, ICCVW 2019*. Department of Industrial and Systems Engineering, University of Iowa, Iowa City, IA 52242, United States: Institute of Electrical and Electronics Engineers Inc.
- [5] Elihos, A.; Alkan, B.; Balci, B.; and Artan, Y. (2019): Comparison of image classification and object detection for passenger seat belt violation detection using NIR RGB surveillance camera images. in *15th IEEE International Conference on Advanced Video and Signal-Based Surveillance, AVSS 2018*. Havelsan Inc., Ankara, Turkey: Institute of Electrical and Electronics Engineers Inc.
- [6] Feng, W.; Yu, W.; and Nan, R. (2022): Deep learning based vehicle seat belt detection algorithm for driver and passenger seat occupants. Pp. 306–10 in *7th International Conference on Intelligent Informatics and Biomedical Sciences, ICIIBMS 2022*. Shanghai Institute of Technology, Shanghai, China: Institute of Electrical and Electronics Engineers Inc.
- [7] Gholamhosseinian, A. and Seitz, J. (2021): Vehicle classification in intelligent transport systems: an overview, methods and software perspective. *IEEE Open Journal of Intelligent Transportation Systems*, **2**(July), pp. 173–94.
- [8] Guo, Huiwen; Lin, H.; Zhang, S.; and Li, S. (2011): Image-based seat belt detection. in *Proceedings of 2011 IEEE International Conference on Vehicular Electronics and Safety, ICVES 2011*. Beijing, China: IEEE.
- [9] Guo, H.; Lin, H.; Zhang, S.; and Li, S. (2011): Image-based seat belt detection. in *2011 IEEE International Conference on Vehicular Electronics and Safety, ICVES 2011*. College of Electrical and Information Engineering, Hunan University, Changsha, China.
- [10] Hosseini, S. and Fathi, A. (2023): Automatic detection of vehicle occupancy and driver's seat belt status using deep learning. *Signal, Image and Video Processing*, **17**(2), pp. 491–99.
- [11] Kannadaguli, P. (2020): FCOS based seatbelt detection system using thermal imaging for monitoring traffic rule violations. in *2020 4th International Conference on Electronics, Materials Engineering and Nano-Technology, IEMENTech 2020*. Kolkata, India.
- [12] Kapdi, R. A.; Khanpara, P.; Modi, R.; and Gupta, M. (2022): Image-based seat belt fastness detection using deep learning. *Scalable Computing*, **23**(4), pp. 441–55.
- [13] Khalid, S. Bin and Hazela, B. (2021): Employing real-time object detection for traffic monitoring. in *Proceedings of the International Conference on Innovative Computing & Communication (ICICC) 2021*.
- [14] Li, W.; Lu, J.; Li, Y.; Zhang, Y.; Wang, J.; and Li, H. (2013): Seatbelt detection based on cascade adaboost classifier. in *Proceedings of the 2013 6th International Congress on Image and Signal Processing (CISP 2013)*. Vol. 2. IEEE.
- [15] Luo, J.; Lu, J.; and Yue, G. (2021): Seatbelt detection in road surveillance images based on improved dense residual network with two-level attention mechanism. *Journal of Electronic Imaging*, **30**(3),.
- [16] Madake, J.; Yadav, S.; Singh, S.; Bhatlawande, S.; and Shilaskar, S. (2023): Vision-based driver's seat belt detection. in *2023 International Conference for Advancement in Technology*. Goa, India: IEEE.
- [17] Maduri, P. K.; Singh, G.; Sharma, S.; Mishra, R. K.; and Mishra, N. K. (2021): Seat belt and helmet detection using deep learning. in *3rd International Conference on Advances in Computing, Communication Control and Networking*. Galgotias College of Engineering and Technology (AKTU), Electronics and Instrumentation Engineering, Greater Noida, India: Institute of Electrical and Electronics Engineers Inc.
- [18] Naik, D. S. B.; Lakshmi, G. S.; Sajja, V. R.; Venkatesulu, D.; and Rao, J. N. (2021): Driver's seat belt detection using CNN. *Turkish Journal of Computer and Mathematics Education (TURCOMAT)*, **12**(5), pp. 776–85.
- [19] Qiao, Y. and Qu, Y. (2021): Safety belt wearing detection algorithm based on human joint points. in *2021 IEEE International Conference on Consumer Electronics and Computer Engineering (CCECE 2021)*. IEEE.
- [20] Qin, X. H.; Cheng, C.; Li, G.; and Zhou, X. (2014): Efficient seat belt detection in a vehicle surveillance application. in *Proceedings of the 2014 9th IEEE Conference on Industrial Electronics and Applications, ICIEA 2014*. Hangzhou, China: IEEE.
- [21] Remeseiro, B. and Bolon-Canedo, V. (2019): A review of feature selection methods in medical applications. *Computers in Biology and Medicine*, **112**, pp. 103375 (1-9).
- [22] Upadhyay, A.; Sutrave, B.; and Singh, A. (2023): Real time seatbelt detection using yolo deep learning model. in *2023 IEEE International Students' Conference on Electrical, Electronics and Computer Science (SCEECS)*. Bhopal, India: IEEE.
- [23] Wang, D. (2022): Intelligent detection of vehicle driving safety based on deep learning. *Wireless Communications and Mobile Computing*, **2022**, pp. 1–11.
- [24] Wang, Z. and Ma, Y. (2022): Detection and recognition of stationary vehicles and seat belts in intelligent internet of things traffic management system. *Neural Computing and Applications*, **34**(5), pp. 3513–22.
- [25] Wu, T.; Zhang, Z.; Liu, Y.; Guo, W.; and Wang, Z. (2019): Driver seat belt detection based on YOLO detection and semantic segmentation. *Journal of Computer-Aided Design and Computer Graphics*, **31**(1), pp. 126–31.
- [26] Yang, D.; Zang, Y.; and Liu, Q. (2020): Study of detection method on real-time and high precision driver seatbelt. in *Proceedings of the 32nd Chinese Control and Decision Conference (CCDC 2020)*. IEEE.
- [27] Yang, Z.; Xiong, H.; Cai, Z.; and Peng, Y. (2019): A new method of vision-based seat belt detection. *International Journal of Embedded Systems*, **11**(6), pp. 755–63.
- [28] Yongquan, J.; Tianshu, W.; Jin, L.; Zhijia, Z.; and Chao, G. (2019): GPU acceleration design method for driver's seatbelt detection. in *2019 14th IEEE International Conference on Electronic Measurement and Instruments, ICEMI 2019*. Changsha, China: IEEE.
- [29] Yung, N. D. T.; Wong, W. K.; Juwono, F. H.; and Sim, Z. A. (2022): Safety helmet detection using deep learning: implementation and comparative study using YOLOv5, YOLOv6, and YOLOv7. in *2022 International Conference on Green Energy, Computing and Sustainable Technology, GECOST 2022*. Miri Sarawak, Malaysia: IEEE.
- [30] Zang, Y.; Yu, B.; and Zhao, S. (2023): Lightweight seatbelt detection algorithm for mobile device. *Multimedia Tools and Applications*, **82**, pp. 24505–19.
- [31] Zhou, B.; Chen, D.; and Wang, X. (2017): Seat belt detection using convolutional neural network BN-Alexnet. in *13th International Conference on Intelligent Computing, ICIC 2017*, pp. 384–95.
- [32] Zhou, B.; Chen, L.; Tian, J.; and Peng, Z. (2018): Learning-based seat belt detection in image using salient gradient. in *12th IEEE Conference on Industrial Electronics and Applications, ICIEA 2017*. Vols. 2018-Febru. College of Computer Science and Technology, Wuhan University of Science and Technology, Wuhan, China: Institute of Electrical and Electronics Engineers Inc.

## Authors Profile



Dr. Sutikno is an assistant professor at the Department of Informatics at Diponegoro University. He received a Doctor of Philosophy (Ph.D.) degree in computer science from the faculty of mathematics and natural sciences from the University of Gadjah Mada, Indonesia. He is currently the head of the Intelligent Systems Laboratory. His current research interests include machine learning, computer vision, and artificial intelligence. He can be contacted at email: [sutikno@lecturer.undip.ac.id](mailto:sutikno@lecturer.undip.ac.id).



Dr. Retno Kusumaningrum is an associate professor at the Department of Informatics, Faculty of Science and Mathematics, Universitas Diponegoro. Furthermore, she is currently participating in the Laboratory of Intelligent Systems. Her research interests include machine learning, natural language processing, computer vision, pattern recognition, and topic modeling. She is a member of the IEEE Computational Intelligence Society, IEEE Computer Society, and ACM. Dr. Kusumaningrum's awards and honors include the Sandwich-Like scholarship award from the Directorate General of Higher Education of Indonesia for visiting the School of System Engineering, University of Reading, Reading, U.K. as a student visitor in 2012, the Best Paper of the Second International Conference on Informatics and Computational Sciences in 2018, first place for Outstanding Lecturer - Universitas Diponegoro for the Science and Technology Category in 2019, and second place for the Best Paper Award of the Third International Symposium on Advanced Intelligent Informatics in 2020. She can be contacted at email: [retno@lecturer.undip.ac.id](mailto:retno@lecturer.undip.ac.id).



Dr. Aris Sugiharto received a Doctor of Philosophy (Ph.D.) degree in computer science, faculty of mathematics and natural sciences from the University of Gadjah Mada, Indonesia. Now, he is an assistant professor at the Department of Computer Science, Faculty of Sciences and Mathematics, University of Diponegoro. He is currently the head of the Computational and Graphic Laboratory. His current research interests include pattern recognition and computer vision. He can be contacted at [arissugiharto@lecturer.undip.ac.id](mailto:arissugiharto@lecturer.undip.ac.id).



Dr. Abdul Karim is currently a Research Professor in the Department of Computer Convergence Software at Korea University, South Korea. He earned his Doctor of Philosophy (Ph.D.) in Computer Science from the University of Gadjah Mada, Indonesia, specializing in the faculty of mathematics and natural sciences. Dr. Karim's research primarily focuses on various facets of artificial intelligence, including natural language processing (NLP), machine learning, deep learning, and specifically Large Language Models (LLM). His work is recognized for advancing the understanding and application of AI technologies in complex computing environments.