Discussion

Our study investigated a method of identifying cyclists in the blind spot of a semi-trailer truck and relaying information to a truck driver to prevent truck-cyclist collisions during right-hook turns. This study aimed to develop a portable device that can accurately and quickly detect cyclists within a blind spot. A deep learning approach was used to create a cyclist detection model and was deployed onto a mini-computer for testing. The findings of each engineering objective are discussed below.

First, the cyclist image dataset presented in this study that combines the CIMAT Cyclist dataset and the Open Synthetic Dataset for Cyclist Detection provides more edge-case scenarios and cyclist instances to improve model performance in real-time (Garcia-Venegas et al., 2021; Thomas et al., 2021). The new auxiliary dataset increases the CIMAT cyclist dataset by 119%. This dataset aims to train cyclist detection models that can generalize well to various cyclist orientations within various environments. Future work to improve this newly proposed dataset is to include images with more diverse locations of cyclists to improve model performance.

From the mAP and inference tests in Figures 2 and 3, the EfficientDet Lite 1 was the most robust, as it maintained a high level of AP while producing inferences at a sufficient speed. The EfficientDet Lite 2 model proved accurate; however, it had a trade-off with an average of 70% worse performance in time per inference. Despite the much higher inference speeds from the MobileNetV2, the model could not generalize well between the datasets, and the mAP needed to meet the criteria for further use. Furthermore, the two EfficientDet trained models proved to generalize well to various cyclist images from either the CIMAT or Open Synthetic Cyclist dataset with accuracies of 90% or higher mAP at the IoU threshold of 0.5 (Figure 2 & 3). In addition, the trained camera-based cyclist detection models are able to match the LiDAR scan accuracies presented by Saleh et al. (2017) (80% mAP 0.5:0.05:0.95). These strong performances with the cyclist detection models allow this device to be used in applications beyond right-hand blind spots. Qualitative analysis of the results from the validation set showed that the models sometimes confused pedestrians with cyclists. These confusions could be attributed to the difficult edge cases the models were trained on from the auxiliary dataset. These models also performed adequately at detecting partial cyclists within a frame and cyclists during poor weather conditions, however, the model generally performed better with cyclists in daylight conditions. Furthermore, validation results show no major difference in the effectiveness of detections in urban and rural areas.

Based on the CAD design and the potential camera placements of the vehicle during the model testing, it was determined that an attachment of the camera on the right rear-view mirror would be able to (a) perform the strongest in detecting oncoming cyclists, and (b) cover a semi-trailer truck's blind spot most effectively during a right-hook turn at an intersection as outlined by Wang et al. (2022). Furthermore, the system's active audible and visual alerts address the concerns for driver attention described by Jannat et al. (2020).

In total, the materials for this design cost $200.00, which would be feasible for the trucking industry to implement as a low-cost, portable, and easily installable system. The installation process was simple—the device needs a USB power outlet, an AUX sound output, and an attachment of the webcam onto the right-rear view mirror and can run cyclist detections almost instantly. Some logistical challenges that may be faced when deploying this device on a wide scale would be making the design components more available to the market. The current shortage in computer components makes it difficult to produce devices such as the one discussed in this study. Another obstacle in making this device more publicly accessible would be making the safety benefits outweigh the investment costs in this technology.

Future work in this field that builds off this study would include real-time testing in various scenarios, widespread testing in the trucking industry, feedback from trucking industry users, implementing the device into other vehicle types, evaluating the usage of other technologies such as LiDAR and ultrasonic detectors, considering other object detection architectures and expanding the auxiliary dataset, as well as evaluating other hardware options such as the Jetson Nano mini-computer. These avenues of work could be explored to reduce truck-cyclist collisions further. Furthermore, object tracking techniques and detailed risk assessment techniques could be used as discussed by Garcia-Venegas et al. (2021). Additional techniques using multi-perspective cyclist detection or diffusion object detection models should be investigated to compare to the object detection models (Chen et al., 2022). Future work could also employ vision transformers to improve awareness of cyclists in a vehicle's blind spot and improve cyclist detection accuracy (Dosovitskiy et al., 2021).

Limitations of this study include the absence of grant funding, computational resources to train deep learning models, and software capabilities to model risk scenarios. It would be most advantageous to test this device on a semi-trailer truck or a similarly-sized vehicle; however, this study could not obtain one for testing purposes.

Conclusion

The objective of this study was to design an accurate visual-based blind spot warning system for semi-trailer truck drivers to reduce the number of truck-cyclist collisions at right-hook turns. To achieve this, the study set three specific objectives: (1) to develop a system that can actively detect cyclists with high accuracy in a semi-trailer truck's blind spot; (2) to create warnings for cyclists in a truck's right-rear blind spot within a short time interval to reduce the risk of collision; and (3) to design a system that is portable and easily installable on most semi-trailer trucks.

In conclusion, the development of an accurate visual-based blind spot warning system for semi-trailer truck drivers can significantly reduce the number of truck-cyclist collisions. By using state-of-the-art lightweight deep learning architectures and a newly proposed cyclist image dataset, the object detection model was able to locate and detect cyclists with high mAP. The device was tested in real-time and demonstrated good performance and feasibility in a model traffic scenario. Further work is needed to optimize and refine the device, but this study shows promise in improving the safety of VRUs such as cyclists.