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Deep Learning for Computer Vision
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Collision Avoidance in Autonomous Vehicles using Computer Vision

This write-up will focus on computer vision used in collision avoidance for autonomous vehicles. This technology is at the core of enhancing road safety, addressing the complex challenges of perceiving the driving environment, predicting potential hazards, and enabling a vehicle to act decisively to protect occupants and other road users. While extensive research and information are available on this topic, this write-up explains it through the findings of three main papers: “Vision-based Driver Assistance Systems: Survey, Taxonomy and Advances,” “Survey of Autonomous Vehicles' Collision Avoidance Algorithms,” and “Machine vision-based autonomous road hazard avoidance system for self-driving vehicles.”

An autonomous vehicle's ability to avoid a collision begins with its ability to perceive its surroundings, which is done through sensor technologies. To create this model, systems use sensor fusion, which combines data from multiple sensor types to enhance accuracy, reliability, and robustness. Cameras recognize and classify objects, Radar uses radio waves to detect objects, and LiDAR systems use laser pulses to generate 3-D maps of vehicle surroundings. The data is used for obstacle detection, localization, and creating environmental models.

After perceiving the object, the algorithm processes the information to plan a safe path and make the next decision, involving machine learning techniques.

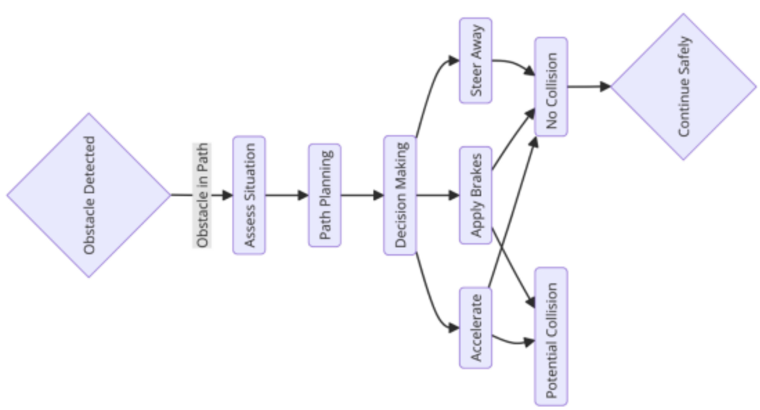

Fig. 1: Framework of collision avoidance algorithm.

The general framework for collision avoidance begins when an obstacle is detected in the vehicle's path. The system assesses the situation, engages in path planning to find a safe route, and makes the next decision (Hamidaoui et al.). Path planning algorithms can employ methods A* or Dijkstra's algorithm, alongside RRT for dynamic settings.

Machine Learning enhances the system's ability to perceive and adapt to new situations with deep learning models, such as convolutional neural networks, which are dominant in object detection and classification. These systems can recognize patterns directly from sensor data and map visual information to driving actions like steering/braking. Reinforcement learning allows vehicles to learn behaviors through trial and error, enabling the system to adapt to changing road conditions and traffic scenarios without being programmed for every possibility. These approaches are used in addition to traditional planning/control methods to create robust systems capable of handling a wider array of challenges.

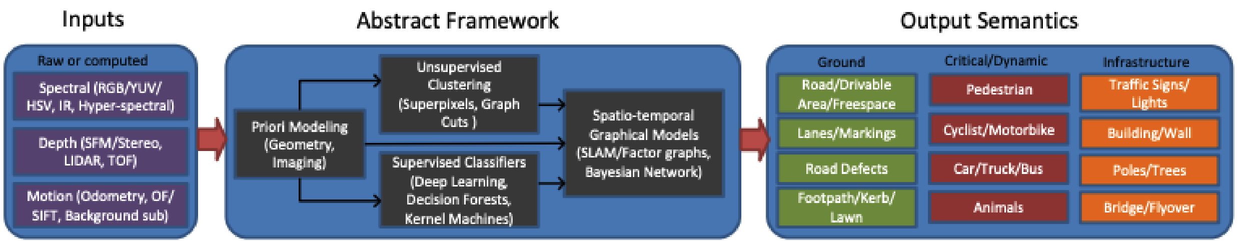

Fig. 2: Generic scalable model for vision ADAS.

The integrated approach described in the previous paragraph is illustrated in the figure above. Inputs from sensors are fed into an abstract processing framework, which then interprets the data and outputs a set of “Output Semantics.” This process allows the environment to be segmented and labeled into ground surfaces, critical/dynamic objects, and infrastructure, enabling vehicles to make informed and context-aware decisions (Horgan et al.).

An example of these ML technologies can be seen in models like YOLO and its variants that are designed to process images from a vehicle’s cameras and identify road users in real time.

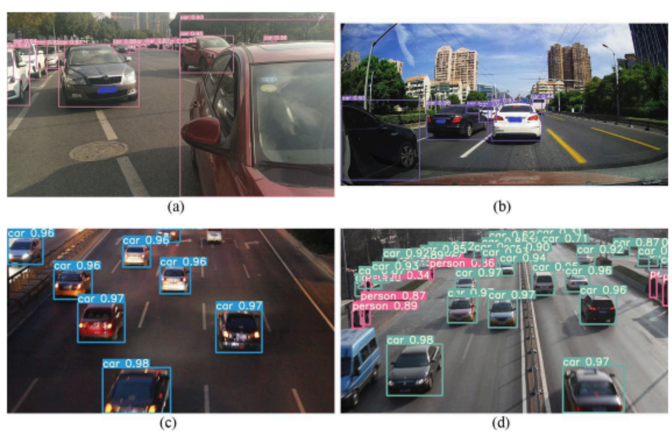

Fig. 3: YOLOv5s targets detect road vehicles and pedestrians.

The model places boxes around detected objects and assigns a classification and confidence score to each detection, providing the vehicle's decision-making system with data about its immediate environment (Qiu et al.).Collision avoidance algorithms perform well in simulations; however, they do not perform well when deployed in the real world, due to unpredictable human behavior, complex traffic patterns, and adverse weather conditions.

Works Cited

Hamidaoui, Meryem, et al. “Survey of Autonomous Vehicles' Collision Avoidance Algorithms.” *Sensors*, vol. 25, no. 395, 10 Jan. 2025.

Horgan, Jonathan, et al. “Vision-based Driver Assistance Systems: Survey, Taxonomy and Advances.” *Valeo Vision Systems*, 2015.

Qiu, Chengqun, et al. “Machine Vision-Based Autonomous Road Hazard Avoidance System for Self-Driving Vehicles.” *Scientific Reports*, vol. 14, no. 12178, 28 May 2024, pp. 1-15.