ANALYSIS OF THE INFLUENCE OF THE SAFETY ZONE ON THE EFFECTIVENESS OF THE ROAD CROSSING CONTROL ALGORITHM FOR AUTONOMOUS VEHICLES

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Objectives

Recent developments in machine learning and control systems are enabling automation of vehicle driving activities for the development of autonomous vehicles (AVs). Through the use of intelligent control systems, there is the search for replacement of humans in the vehicle driving. However, one of the great challenges is to ensure that these controls operate at an adequate level of critical safety to avoid accidents with material losses and fatalities. This work analyzes, in a comparative way, the impact of two distinct approaches of Safety Zone (SZ) on the efficiency, from a safety point of view, of an autonomous lane crossing control algorithm. The SZ is a virtual region around the vehicle that expands its physical dimensions, which are considered by the AV control to ensure its safe movement.

Methods and Procedures

This study uses a computational modeling and simulation framework developed in cooperation between the Safety Analysis Group of the Escola Politécnica da USP (GAS/EPUSP) and Ericsson (Brazil and Sweden), focused on the study of the behavior of AVs in traffic scenarios [1]. This framework (Fig. 1) integrates an open source vehicle traffic simulator (OpenDS) and Matlab, which runs the AV control algorithm. Through this integration, it is possible to simulate the behavior of AVs immersed in a scenario of vehicular and people traffic. The information generated in the simulator is transmitted and processed in the Matlab environment. Afterwards, the decision of the algorithm is returned to the simulator, being converted into a command in the AV, completing the working cycle of the framework.

The same configuration and scenario of traffic crossing between two lanes (Fig. 2) adopted in [2] was used. Thus, it was possible to use the previous results as a benchmark for comparison for the new configuration adopted in this study.

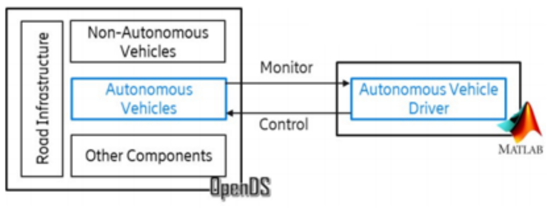

Fig. 1 - Framework model - OpenDS integration (simulation) and Matlab (AV control algorithm)

In both SZ approaches, the objective of the control algorithm is to determine the target (safe) speed - managed through acceleration and braking commands - of the AV in the simulated environment. Furthermore, the control algorithm is only embedded **in the AV that travels on Road 1**, being responsible for its safe conduction through the intersection. Vehicle control obtains situational awareness from vehicle-to-vehicle communication (V2V), in addition to information acquired by the AV sensors themselves.

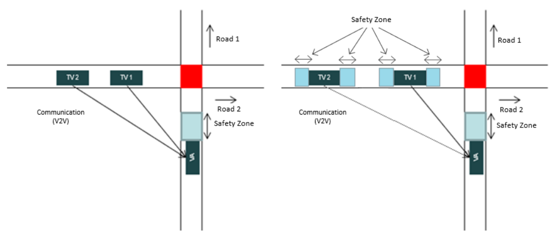

Fig. 2 - To the left benchmark control crossing scenario - To the right control scenario of the new control proposal

In [2], the SZ was adopted only in the AV. Furthermore, the target speed is determined through comparisons between the current speed and the midpoint speed between each pair of consecutive vehicles (1st and 2nd vehicles, 2nd and 3rd vehicles, successively).

In the present analysis, the SZ was adopted for both the AV and the vehicles traveling on Route 2. In addition, adaptations in the calculation of the target speed to carry out the safe crossing were implemented in the control to accommodate the different SZ configurations. For the AV, 3 fixed SZ configurations (2, 3, 4 meters) were tested and for the vehicles on Road 2 another 3 fixed SZ configurations (0, 1, 2 meters), resulting in 9 combinations of SZ pairs.

To enable a comparison between the two approaches (between [2] and current), the same parameters were collected. Thus, the vehicles on Road 2 travel at 15 m/s. For V2V communication, a sampling frequency (F) of 10 Hz and an end-to-end latency of 1 second were adopted. The efficiency of controls and the size of the SZ is measured by the accident rate (collision, C), emergency stop rate (total stop, P) and the minimum distance average (MD) between the geometric centers of the AV and any vehicle from Road 2, observed at the intersection.

The experiment considered 5 maximum speeds (MSs) for the AV and 9 pairs of combinations of SZs of the AV and Road 2 vehicles, totaling 45 scenarios. For each scenario, 50 executions were performed (totaling 4500 executions for this study). In each execution, the result can be an effective crossing, collision or stop, allowing the calculation of C and P. Scenarios with different AV MS limits (11, 12, 13, 14 and 15 m/s) were used.

Results

Tab. 1 consolidates the results of the experiment. It can be seen that, for the benchmark, the AV does not collide for the two smallest MSs, executing full stop at all times. In addition, for MSs of 13 and 15 m/s, the AV suffers some collisions, with the highest MS having the highest value of C. With the new configuration, in none of the MSs there is a total stop, and it can be observed the same accident rate for speeds of 12 and 15 m/s. For MS of 15 m/s there is a notable reduction in the accident rate. Finally, by the average of the MD for each MS range, it is possible to infer the degree of the AV collision risk, with the inversely proportional relationship between MD and the collision risk.

Tab. 1 - Results of comparison between proposals for the use of a safety zone (B - Benchmark; N - New approach)

AV's Maximum Speed (m/s)	11		12		13		14		15	
	B	N	B	N	B	N	B	N	B	N
Collision Rate (%)	0%	0%	0%	0.5%	3.2%	0%	0%	0%	13.6%	0.5%
Total Stop Rate (%)	100%	0%	100%	0%	0%	0%	0%	0%	0%	0%
Average Minimum Distance (m)	19.9	8.4	7.78	8.14	7.15	8.9	9.1	9.7	6.85	8.64

Conclusions

The use of SZ in all vehicles showed a significantly better result compared to the use of SZ only in the AV (benchmark), given that the accident rate for most of the MSs considered remained equal to zero or were reduced. Total stop rates did not occur for any MS configuration tried. Also, it is possible to notice that the MDs for all MSs converged to a distance that avoids collisions. Consequently, the use of SZ for all vehicles proved to be promising not only to guarantee critical safety, but also to guarantee greater traffic flow in the simple crossing scenario.

Bibliographic References

[1] L. F. Vismari et al., “A simulation-based safety analysis framework for autonomous vehicles – assessing impacts on Road Transport Systems safety and efficiency,” in Proceedings of ESREL 2018, pp. 2067--2075.

[2] G. K. G. Shimanuki, “Influence of the safety zone on risk of accidents with autonomous vehicles”, SIICUSP 2020