Information sharing among autonomous vehicles crossing an intersection

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1 Introduction

Autonomous vehicles can react faster than humans, they have more accurate perception and do not get distracted, sleepy or intoxicated. Autonomous vehicles could also increase the capacity of our current roads by allowing cars to be driven more closely to each other. Accordingly, driverless cars seem to be imminent. One of the challenges with autonomous vehicles is their performance at intersections. This performance directly depends on the level of cooperation between the vehicles.

2 Decentralized control method

In this paper, we use the previously introduced method for coordinating autonomous vehicles at intersections using a decentralized navigation function (DNF) [1]. This multi-vehicle system is defined by the interaction of vehicles. Therefore, one subordinate goal is to specify which information should be shared among the vehicles. This method was developed so that vehicles have smoother trajectories, which could result in less energy consumption and more intersection flow. The dynamic motion of each vehicle along its path was taken into account as well as constraints related to speed, acceleration and braking. The proposed navigation function guarantees a collision free trajectory for each vehicle all the way to its destination [2] only using the information about the position of the other vehicles.

In this work we investigate how sharing other information with other vehicles rather than just the position could improve the performance of the whole system. For this purpose we consider the cases where vehicles can share information about their speed, inertia, and their intention at the intersection. To be able to use the information we add appropriate terms to the initial navigation function, so the vehicles use this information to coordinate and pass the intersection without collision.

3 Simulation results

We evaluate the proposed method of navigation function with different information sharing policies and compare them with traditional traffic lights (conservative case) and centralized optimal controllers (most energy-efficient in theory but not applicable in reality). To compare, we define two different criteria. The first is the energy consumption of all vehicles, calculated by integrating acceleration and braking over time. The second is the maximum achievable flow at the intersection. Results are shown in Table 1. Results are normalized to that of traffic lights for the sake of comparison.

Table 1.Results of the comparison of intersection control methods according to two criteria.

Control method	Energy consumption	Intersection flow
Traffic Lights	1	1
Decentralized navigation function	0.52	1.34
Decentralized navigation function with speed	0.49	1.41
Decentralized navigation function with inertia	0.31	1.71
Decentralized navigation function with vehicles intention	0.41	1.79
Centralized controller	0.22	1.85

The results listed in the table show that using DNF introduces a significant improvement (48%) comparing to traffic lights (taken as the base line) even with using the basic information of other vehicles. By taking the inertia of vehicles into account, the proposed method can optimizes energy consumption up to 69% of traffic lights. Having information about the intention of other vehicles at the intersection can also minimize energy consumption, because vehicles can manifestly ignore vehicles that don't cause danger to them. Sending the speed of one vehicle to the others does not drastically change the performance of the system. This point was not unpredictable because using a navigation function is a timestep process in which vehicles can compute the speed of other vehicles using the current and previous data of their position. The method of decentralized navigation function with inertia is only 29% less effective than the centralized one, while being easily implementable. This paves the way for on-board energy optimization by indirectly giving priority to heavier vehicles.

4 Conclusions and future works

DARPA Challenges have shown that complete automation of driving task is already technically feasible [3]. This new coordination approach could ease the future adoption of autonomous vehicles in intelligent transportation systems. Moreover, it could also provide an upper bound of performance for semi-autonomous vehicles equipped with driving assistance systems. An interesting future direction is to study the sensitivity of our approach and investigate cases of limited state information and communication failures.

References:

[1] Makarem, L. and Gillet, D, "Decentralized Coordination of Autonomous Vehicles at intersections", 18th IFAC world congress, Milano, Italy, August 28 - September 2, 2011

[2] Fankhauser, B., Makarem L. and Gillet D., "Collision-Free Intersection Crossing of Mobile Robots Using Decentralized Navigation Functions on Predefined Paths", IEEE international conference on cybernetics and intelligent systems, Qingdao, China, September 17-19

[3] *DARPA Urban challenge*, [Online]. Available: http://www.darpa.mil/grandchallenge