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A Review on Leader-Follower Based Path Optimization in Vehicle Platooning

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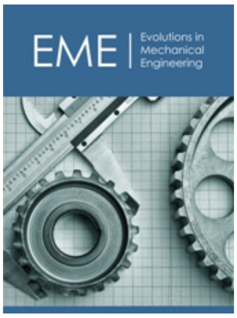

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Introduction

In self-driving cars, especially when the vehicles are travelling as a cluster in which the first vehicle acts as a leader and the other vehicles act as followers, there is a need for proper communication on the selection of path. This will help the vehicles to reach their destination without any intermittent communication hurdles that leads to accidents and traffic congestions. To achieve this, the vehicles on the road are formed as a platoon in which the first vehicle will send the communication to all the follower vehicles to line up behind the leader. This will help them to automatically form a string formation to stay close to each other on the highway without any traffic difficulties. This survey report gives an overview on how nature inspired techniques could be applied to achieve vehicle platoons to smoothly run on the highway in an optimized manner.

Vehicle Platooning

In vehicle platooning, a group of vehicles maintain a close proximity when they are moving as a group. Here, the vehicles are maintaining a short space between them with respect to their speed and velocity. When such platoons are formed, to make the driving effectively, the vehicle at the first position will act as a leader and it represents the trajectory and velocity as reference parameters. While the vehicles are moving as a platoon, the other vehicles are controlled by the leader. Each vehicle in the platoon gets the order from the leader to move on [1].

This makes an effective traffic management in an automated manner with less time and improved benefits. It also eliminates the speed controlling measures done by the manual drivers while driving on the highways. In vehicle Platoon, the vehicles are considered as a single entity and improved safety is achieved. In the Leader-Follower relationship, better co-ordination among the vehicles is achieved.

In early vehicle platoon concepts, the mechanical coupling resembled something like that as in a train. In it, the drive-by-wire steering and throttle, as well as GPS, Bluetooth, and other modern technology allow computers to take control of cars. In them, the 5G communications may assist in making Platooning a safe option due to the increased volume of data to process [1].

However, the research question is how to optimize the process of coordination between the vehicles? And How to optimize the path selection process so that vehicle platoon helps reduce the time and cost associated with reaching the destination?

Leader-Follower based Path Optimization

In the case of self-driving multi-vehicle systems, the coordination between them has received huge attention. In such systems, 'String instability' occurs when there is any position or velocity mismatch occurs. This results in the fluctuations and ultimately leading to accidents and traffic congestion in the following vehicles. These side effects need to be addressed efficiently using possible solutions. One such solution is leader-follower relationship between the vehicles in the platoon. In this, the leader sends commands to the follower vehicles to follow some distance, speed and velocity to reduce the traffic congestion. The literatures indicate a lot of works in this leader-follower based vehicle platoon formation.

Wen and Guo [2] have investigated the problems related to the controlling of leader-follower based vehicle platoon. In that, they have proposed a platoon control algorithm in which platoon control is modeled as a switched platoon control system with a connectivity-status-matrix-dependent controller. They have used this controller to get 'string stability' and a 'zero-steady-state spacing error'.

Jiang et al. [3] have implemented a varying speed of leader in the platoon. In their work, to estimate the speed, acceleration rate and the position of the leader, an observer is designed by each follower. The observer has a scalar value of all these parameter values. They have introduced a heuristic search algorithm with a bisection algorithm to find the controller parameter conditions with fixed time headway to achieve string stability.

Cheok et al. [4] have exhibited that, path planning is a key factor in which a leader will have self-organizing characteristic while formulating platoons with safe and graceful movements. They applied Smooth-path-planning algorithm which produces easy to implement robotic movements. Their algorithm was derived from Lyapunov stability criterion and dynamical control synthesis. Their results indicate that, the SPP algorithm results human actions in terms of autonomous decision making.

Cao et al. [5] have presented a strategy in which the upstream area is divided into two zones namely regulation zone and merging zone. The vehicles in the platoon to have large gap between them instead of small and scattered gaps to accommodate vehicles merged in-between in the regulation area, a non-linear programming model is implemented to balance the risks that addresses both traffic capacity and safety. A sorting algorithm is proposed in the merging zone, to design the trajectories to do lane-change in the regulated platoons.

Timmerman and Boon [6] have studied the intersection access control between autonomous vehicles while creating vehicle platoons. In their work, they suggested an option to achieve high speed at the interactions by slowing down the vehicles speed before the interaction place so that, each vehicle can traverse at high speed at the intersection point.

Faten et al. [7] have presented a comparative study of various algorithms applied in vehicle platooning based on their communication modes and validation strategies. Sturm et al. [8] have provided the advantages in keeping the distance between the vehicles in the platoon as small. According to their study, they have found energy savings, congestion control and improvement in safety measures when the inter-vehicle distance is kept as minimum.

Farag et al. [9] have proposed a decision-making optimization algorithm with deep learning for cooperative driving in the vehicle platoon. They have optimized the joining speed profile of the vehicles in the platoon using Sequential Quadratic Programming and Genetic Algorithm (GA). They have also proposed a deep neural network to retain the accuracy of the optimizer and reduction of computational cost.

Conclusion

As cooperative driving is one of the most important and emerging area of research especially in smart cities and smart transport applications, optimizing the path and other related parameters is the need of the hour. This survey has systematically performed a brief literature survey on this area, so that the researchers who are working in this problem can focus their work to achieve efficiency in vehicle platoon. In the brief survey given in this report has indicated that there are various algorithms proposed to reduce the cost and improve the safe transportation. The recent works indicated the application of several optimization algorithms to get the appropriate path for the vehicles using machine learning and AI based neural networks. Apart from this, the need for regulated platoons using Leader-Follower relationship with leader taking intelligent decisions to get the optimized path is tremendous. This paper provides an eye-opener for the researchers and academicians to make them ready to do further research works in this novel area of research.

References

1. Mala DJ, Reynold PA (2020) Intelligent agents in vehicle platooning for smart cities, IEEE Smart Cities, Newsletter.
2. Wen S, Guo G (2019) Control of leader-following vehicle platoons with varied communication range. IEEE Transactions on Intelligent Vehicles 1(1): 99-101.
3. Jiang W, Abolfazli E, Charalambous T (2021) Observer-based control for vehicle platooning with a leader of varying speed. arXiv: 2108.09497.
4. Cheok K, Iyengar K, Oweis S (2019) Smooth trajectory planning for autonomous leader-follower robots, EPiC Series in Computing, Proceedings of 34th International Conference on Computers and Their Applications 58: 301-309.
5. Cao D, Wu J, Wu J, Kulcsár B, Qu X (2021) A platoon regulation algorithm to improve the traffic performance of highway work zones, Computer Aided Civil and Infrastructure Engineering 36(7): 941-956.
6. Timmerman RW, Boon MAA (2021) Platoon forming algorithms for intelligent street intersections, Transportmetrica A Transport Science 17(3): 278-307.
7. Fakhfakh Faten, Tounsi Mohamed, Mosbah Mohamed (2020) Vehicle platooning systems: Review, classification and validation strategies. International Journal of Networked and Distributed Computing 8(4): 203-213.
8. Sturm Timo, Krupitzer Christian, Segata Becker M, Christian (2021) A taxonomy of optimization factors for platooning. IEEE Transactions on Intelligent Transportation Systems. 22(10): 6097-6114.
9. Farag A, Hussein A, Shehata OM (2020) Heterogeneous platooning decision making algorithm based on optimization and deep learning. IEEE 23rd International Conference on Intelligent Transportation Systems (ITSC), pp. 1-7.

