Conference Paper

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CISTER Research Centre
Polytechnic Institute of Porto (ISEP P.Porto)
Rua Dr. António Bernardino de Almeida, 431
4200-072 Porto
Portugal
Tel.: +351.22.8340509, Fax: +351.22.8321159
E-mail: enpvf@isep.ipp.pt, aska@isep.ipp.pt, sev@isep.ipp.pt, emt@isep.ipp.pt
https://www.cister-labs.pt

Abstract

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An Integrated Lateral and Longitudinal Look Ahead Controller for Cooperative Vehicular Platooning*

Enio Vasconcelos Filho[1][0000−0001−5459−6821], Ricardo Severino[1][0000−0002−4215−3238], Anis Koubaa[2][0000−0003−3787−7423], and Eduardo Tovar[1][0000−0001−8979−3876]

[1] CISTER Research Centre, ISEP, Rua Alfredo Allen 535 4200-135 Porto, Portugal
`{enpvf, rarss, emt}@isep.ipp`
[2] Prince Sultan University, Saudi Arabia
`akoubaa@psu.edu.sa`

Abstract. Cooperative Vehicular Platooning (CoVP), has been emerging as a challenging Intelligent Traffic Systems application, promising to bring-about several safety and societal benefits. Relying on V2V communications to control such cooperative and automated actions brings several advantages. In this work, we present a Look Ahead PID controller for CoVP that solely relies upon V2V communications, together with a method to reduce the disturbance propagation in the platoon. The platooning controller also implements a solution to solve the cutting corner problem, keeping the platooning alignment. We evaluate its performance and limitations in realistic simulation scenarios, analyzing the stability and lateral errors of the CoVP, proving that such V2V enabled solutions can be effectively implemented.

Keywords: Cooperative Platooning · Safety · V2V.

1 Introduction

Cooperative Vehicular Platooning (CoVP) is an emerging application among the new generation of safety-critical automated vehicles that hold the promise to potentiate several benefits such as increasing road capacity and fuel efficiency and even reducing accidents. These benefits arise from groups of vehicles traveling close together, supported by vehicle-to-vehicle communication (V2V), vehicle-to-infrastructure (V2I) communication, or both (V2X). This challenging application encompasses different topics, such as cooperative control models [1], V2V and V2I communication [2], energy efficiency [3], safety, interaction with other vehicles and platoons, among others. The V2V and V2I has an important role in increasing the performance of the resulting platoons, comparing to those obtained

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without communication between the vehicles [4,5]. Actually, in some cases, the AVs implementation with no communication, mixed with human driven vehicles can even decrease the traffic speed, given the acceleration profile of the AVs [6,7]. Thus, the complexity of these systems of systems is naturally high.

Regarding the CoVP controller alone for instance, its development integrates several control areas. The error amplification and disturbance propagation in a platoon is studied in [8], where the authors analyze the problem of controlling a string of vehicles moving in a straight line. This study shows that even with a constant speed, the disturbance is propagated through the platoon, causing instability in the spacing error. Another important challenge is on how to manage the *cutting corner problem* [9], where the vehicles have the same orientation but do not follow the leader's trajectory. This is particularly important, since interestingly, several of the CoVP control models do not address lateral control, and those that do, ignore the advantage of relying upon V2X communications. A compromise is found in the work presented in [10], by proposing an integrated longitudinal and lateral controller which integrates an on-board radar sensor with V2V communication.

In [11], the authors propose an integrated lateral and longitudinal controller using the preceding vehicle acceleration, keeping the platooning safety with three main controllers. These controllers are: a feed forward controller for the string stable longitudinal control, a Corrective constraint controller and a MPC controller for the lateral problem. However, the error propagation through the platoon and the cutting corner problem are not addressed. A solution to it was proposed in [12] with a Look Ahead Controller (LAC). In this work, the controller estimates a trajectory between each leader trajectory point. However, there is a lack of research that focuses solely on V2V communications to accomplish CoVP control. This possibility is becoming increasingly scalable and viable with the advent of 5G integrated communications, and can be useful, particularly in scenarios where vehicle sensors can become impaired and provide incorrect readings, providing an extra layer of safety. In addition, relying upon V2V makes these applications more flexible and cheap, as they are not so dependant on expensive vehicle sensors. However, to enable such approach, more research is needed to fully understand its potential and limitations, for instance, on the impact of the network Quality of Service (QoS) upon the CoVP safety and performance. Nevertheless, to support such research, one needs to rely upon functional cooperative control models enabled by V2V communications in the first place. It is mostly with this in mind, that we decided to take this first step in this work.

In this paper, we propose a V2V-enabled CoVP Look Ahead Controller (LAC) with low complexity, that is able to provide good results in keeping the platoon distance, alignment and safety, reducing the impacts of the errors though the platoon and solving the cutting corner problem. The use of a well know base controller as a PID reduces the system complexity, in order to increase the system implementation in real life scenarios. The main simulator view can be observed in Fig. 1. The main contributions proposed in this work are: (1)

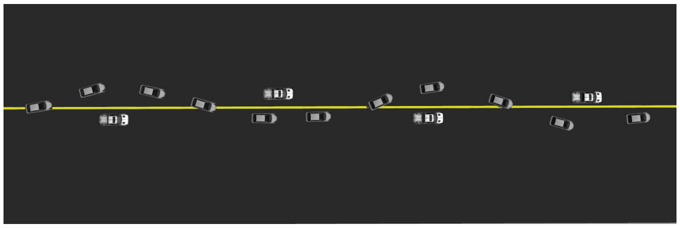

Fig. 1. Platooning View

The development of a longitudinal and lateral CoVP controller that relies only in V2V communications; (2) Improvement of the lateral controller to solve the cutting corner problem; (3) The development of a LAC strategy to increase the platoon's stability even with a large number of vehicles, reducing the disturbance propagation problem, presented in [13]; and (4) a safety analysis of the CoVP controller in a realistic scenario, with trajectory changes of the leader and obstacle avoidance. All the scenarios rely upon a robotics simulator, demonstrating that this controller and proposed mechanisms can be implemented in reality.

In the remaining of this paper, we present a problem formulation in Section 2, describing the platoon model. In Section 3, we describe the control models that were implemented and the simulation environment is presented in Section 4. In Section 5, we present the designed scenarios for the control model evaluation and an analysis about each one. The Conclusions and the suggestion for future works are presented in the last section.

2 PROBLEM FORMULATION

Table 1. Definition Terms

Abreviation	**Meaning**
i	Vehicle Identification
SV_i	Subject Vehicle i
$m_{SV_i,SV_{i+1}}$	Exchanged Messages Between The vehicles
$D_{SV_i,SV_{i+1}}$	Inter Vehicles Distance
d_ref	Objective Range
SD	Safety Distance
ε_i	Distance Error
$\theta_{e,i}$	Lateral Error
B_i	Bearing Error
SA_i	Steering Angle
$E\theta_{i+1}$	Lateral Error (with Bearing)

2.1 Basic Platoon Model and Stability Analysis

This work presents a CoVP model based on the ITS european standard [14], where a V2V communication model called Predecessor-Follower [15] is defined. Seeking to facilitate the understanding of the formulation proposed here, the table 1 presents the main terms used and their nomenclatures. Each vehicle is modeled as unicycle in a Cartesian coordinate system. The platoon is composed of $n \in \mathbb{N}$ vehicles. The full set of vehicles can be defined as $SV_n = \{i \in \mathbb{N} | 0 \leq i \leq n\}$, with a set of *Subject Vehicles*, where SV_0 is the first vehicle and the platoon's Leader. Each SV_i can be a local leader of SV_{i+1} and a follower of SV_{i-1}. The platoon's model is exemplified in Fig. 2.

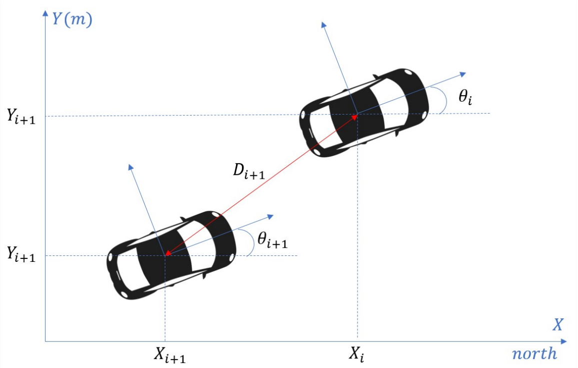

Fig. 2. Platoon Model

Each SV_{i+1} receive data from SV_i, containing: the global position of SV_i - $(x_i(t), y_i(t))$, speed $(v_i(t))$, acceleration $(a_i(t))$, steering angle $(SA_i(t))$ and Heading $(\theta_i(t))$. The messages can be defined as $m_{SV_i,SV_{i+1}}(t)$, where SV_i is the sender and SV_{i+1} is the receiver. Once the vehicle SV_{i+1} receives $m_{SV_i,SV_{i+1}}(t)$, it performs the control process to accomplish the tracking goal. The SV_{i+1} should gather it's own orientation, θ_{i+1} and the inter distance between SV_i and SV_{i+1}, $d_{SV_i,SV_{i+1}}(t)$.

The inter vehicles spacing methodology is the *constant time-headway policy* (CTHP) [16], that uses the current speed of the vehicle to define the safety distance. In CTHP, the objective range (d_{ref}) in this policy is $d_{ref}(t) = SD + T_h v_i(t)$, where $SD > 0$ is the safety distance, T_h is the defined time headway, generally between 0.5 and 2 seconds, and $v_i(t)$ is the followers speed.

The platoon stability is defined as the spacing error between the real and the desired inter-vehicle spacing [13]. The spacing error between SV_i and SV_{i+1} can be determined using

$$\varepsilon_i(t) = d(SV_i(t), SV_{i+1}(t)) - d_{ref} \tag{1}$$

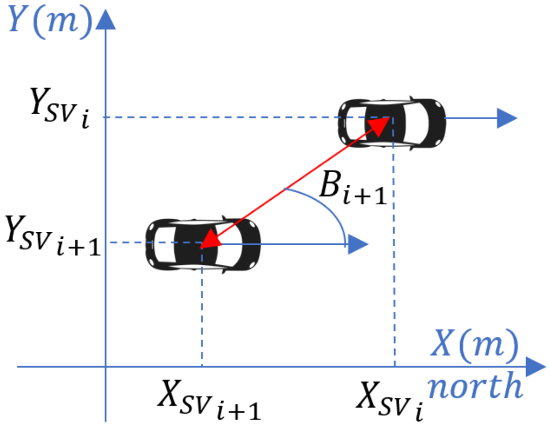

Fig. 3. Bearing Error

,where $d(SV_i(t), SV_{i+1}(t))$ is the Euclidian distance between $SV_i(t)$ and $SV_{i+1}(t)$. The steady state error transfer function is defined by

$$H(s) = \varepsilon_i / \varepsilon_{i-1}, \tag{2}$$

, based on the $\mathcal{L}_2$ norms, where the platoon stability is guaranteed if $\|H(s))\|_\infty \leq 1$ and $h(t) > 0$, where $h(t)$ is the impulse response corresponding to $H(s)$ [4]. This equation defines the *local platoon stability*. Alternatively, the string stability can be defined as $\mathcal{L}_\infty$, in order to to guarantee the absence of overshoot for a signal while it propagates throughout the platoon. This performance metric is the same as characterized in [17], which defines the worst case performance in the sense of measuring the peak magnitude of the spacing distance between the vehicles, defining a *global platoon stability*.

2.2 Lateral error

In a CoVP, the SV_{i+1} should perform the same path as the SV_i, based only on the received information. However, as $d_{ref}(t) \geq SD$, when SV_i is in position $(x_i(t), y_i(t))$, SV_{i+1} is in position $(x_{i+1}(t), y_{i+1}(t))$, with a speed of $(v_{i+1}(t)\cos(\theta_{i+1}(t)), v_{i+1}(t)\sin(\theta_{i+1}(t)))$, there is a *delay* between the current position of SV_{i+1} and the *desired* position of SV_i. Then, the SV_{i+1} controller will receive and store the messages $m_{SV_i, SV_{i+1}}$ from time $t - T_0$ until t, when SV_{i+1} reach the same position as SV_i in time t. The lateral error $\theta_{e,i+1}$ in the , refers to the difference between the heading of $SV_i(t - T_0)$ and $SV_{i+1}(t)$. This error is defined by

$$\theta_{e,i}(t) = \theta_{SV_i}(t - T_0) - \theta_{SV_{i+1}}(t) \tag{3}$$

The time of actuation over the SA_{i+1}, provided by $\theta_{e,i}(t)$, is responsible for the cutting corner error, since there is a difference between $(x_i(t-T_0), y_i(t-T_0))$

and $(x_{i+1}(t), y_{i+1}(t))$. This error can cause a bad alignment between SV_i and SV_{i+1}, even with a $\theta_{e,i}(t) = 0$, given that the follower can start to perform a curve at a different instant as the leader. This bad alignment is called *bearing error*, $B_i(t)$, and can be seen in Fig. 3. The bearing error rises from accumulated lateral errors of SV_{i+1} while following SV_i particularly in curves and should be calculated when $\theta_{e,i}(t) \approx 0$. In our work, we defined this threshold as $0.15rad$. This limit was defined to indicate that the desired SV position is ahead of the current SV_i position, at a maximum angle of up to 16 degrees. This value prevents Bearing performance from causing a correction beyond the vehicle's limits, causing instability, namely in sharp turns. The Bearing error is defined as:

$$B_i(t) = \arctan(\frac{x_i - x_{i+1}}{y_i - y_{i+1}}). \tag{4}$$

3 CONTROL MODELS

We divide the implemented control methods for the SV_is in Longitudinal and Lateral controllers. Both were defined with as a low complexity PID controller model. In this work, we also propose a LAC that modifies both longitudinal and lateral controllers, increasing the platoon safety.

3.1 Longitudinal and Lateral Controllers

The longitudinal controller is responsible for ensuring the safety of the platoon, maintaining the inter distance between SV_i and SV_{i+1}, adjusting v_{i+1}. The main PID controller equation for SV_i in time t is:

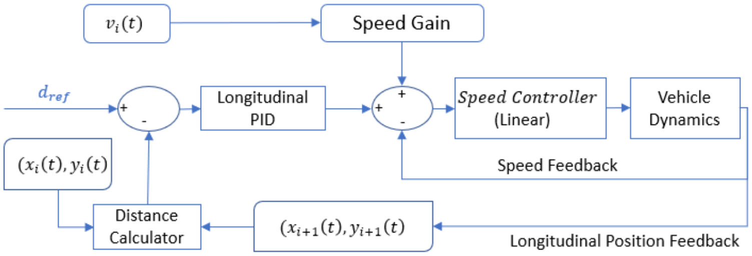

Fig. 4. Longitudinal Controller Model

$$v_{i+1}(t) = K_P * \varepsilon_{i+1}(t) + K_I * \int \varepsilon_{i+1}(t) + K_D * \frac{\Delta\varepsilon_{i+1}(t)}{dt}, \tag{5}$$

where K_P, K_I and K_D denote respectively the Proportional, Integrative and Derivative gain constants. The full controller is presented in Fig. 4, where we

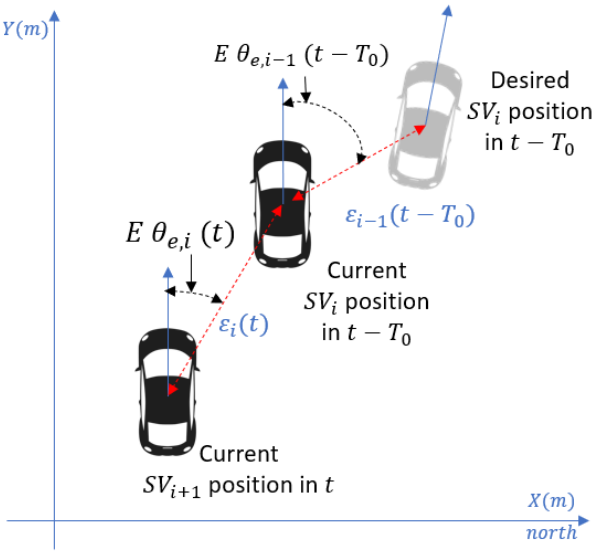

Fig. 5. The LAC consider the difference between the current position of SV_{i-1} and the desired position

assume that the time constant of the actuator is much bigger then the time constant of the motor.

The lateral controller is responsible for the vehicle's heading. The main equation of the PID controller is presented in eq. 6.

$$SA_{i+1}(t) = K_P * e\theta_{i+1}(t) + K_I * \int e\theta_{i+1}(t) + K_D * \frac{\Delta e\theta_{i+1}(t)}{dt}, \tag{6}$$

Where $e\theta_{i+1}(t)$ is defined in (7) and depends of the bearing adjust actuation.

$$E\theta_{i+1}(t) = \begin{cases} \theta_{e,i+1}(t) + B_{i+1}(t), & \theta_{e,i+1}(t) \leq 0.15 \\ \theta_{e,i+1}(t), \quad \theta_{e,i+1}(t) > 0.15 \end{cases} \tag{7}$$

3.2 Look Ahead Controller - LAC

The PID controller is typically reactive, thus, when facing a abrupt change of setpoint, the adjustment can saturate the actuator and cause oscillations or instability. In the CoVP, this effect is observed particularly after closed curves and in quick re-adjustments of speed with a cumulative effect throughout the platoon. In many situations, this effect is reduced given the nature of the test track, particularly when using only long straight roads with few curves. However, in a more realistic scenario, the oscillations of the platooning can cause instability and decrease the system's safety.

The proposed LAC adds an error information about $SV_i, i > 0$ in the controller of SV_{i+1}. This information is transmitted to SV_{i+1} in order to reduce the disturbance propagation, allowing SV_{i+1} to compare its position with SV_{i-1} position, keeping the main reference in the SV_i. This approach also avoids the need for the leader to send messages to all platoon cars, which allows the increase of the platoon's size.

As demonstrated in [12], analysing the platooning, the disadvantage from the common LAC is that the SV_{i+1} lateral position is correct only in a straight line, compared with SV_i. This leads the system to the cutting corner problem, since there is no information about the trajectory of the leader. There is also the increasing error provided by the difference between the current position of SV_{i+1} and the desired position, provided by the path performed by SV_i. Assuming that this error exist, are greater then 0 and are denoted by $\varepsilon_{i+1}(t)$ and $E\theta_{i+1}(t)$, the error between the SV_i and SV_{i+2} increases in each curve. So, the proposed look ahead incorporates the difference between the current position of SV_{i+1} and its desired position, increasing the correction to be performed by SV_{i+2}. In this case, the LAC reduces the difference between the path provided by the platoon's leader and the rest of the followers, as depicted in fig. 5. The new errors can be defined, $\forall SV_i, i > 1$, as:

$$\varepsilon_i(t) = \varepsilon_i(t) + \varepsilon_{i-1}(t - T_0) \tag{8}$$

$$\theta_{e,i}(t) = e\theta_{e,i}(t) + e\theta_{e,i-1}(t - T_0) \tag{9}$$

4 SIMULATION ENVIRONMENT

Given the complexity and safety-critical nature of these CoVP systems of systems, one must carry out extensive validation before any real deployment in vehicles. However, to achieve this, one must rely upon realistic simulators, that can effectively replicate the behaviour of the vehicles as close as possible. Some simulators have been presented, such as [18], where the microscopic characteristics of the CoVP can be analyzed together with the enabling communications. Also robotic testbeds [19] can enable their validation in platforms quite close to a real vehicle. In this work, we implemented the CoVP controller and associated mechanisms over the CopaDrive simulator, so that after the controller's performance evaluation, we could easily shift focus into the communications' impact as a future work. This simulation environment was built using the Robotic Operating System (ROS) in tight integration with the robotics simulator Gazebo. Vehicular communications are emulated via ROS topics using its flexible publish/subscribe middle-ware. The vehicle model is one of a Toyota Prius [20], which replicates the vehicle's main characteristics, such as acceleration, breaking, friction and weight. This enabled us to simulate in a realistic fashion the behavior of the platooning agents in a microscopic way, analyzing issues such as wheel angles, skidding, among others. Similarly, it was also possible to analyze each vehicle's lateral deviation in detail, allowing the evaluation and improvement of the lateral controller.

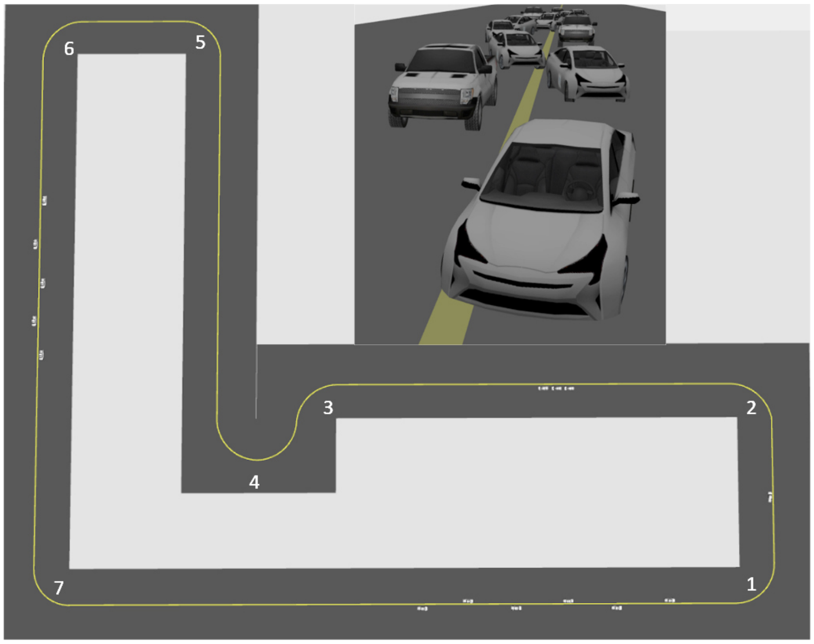

Fig. 6. City Circuit

In this work, V2V communication is simulated using the ROS topics, as presented in Fig. 7, in a Linux Ubuntu 18.04.6 Bionic, with Gazebo 9.0 and ROS Melodic. The running PC has a Intel® Core® i7-975H CPU, with 16 MB RAM memory and a NVIDIA Geforce GTX 1650. Every vehicle in the platoon publishes its own information in the $car_i/TXNetwork$ in a frequency of $33Hz$ - the maximum frequency proposed in [14].

Those topics are all republished by a ROS topic *Network_Simulation* in another topic called $car_i/RXNetwork$. So, the SV_i subscribes to the respectively $car_i/RXNetwork$ topic and perform the defined control actions. As the proposed V2V communication uses a broadcast model, every vehicle receives all the data from other vehicles in the network but only uses the corresponding SV_{i-1}. This architecture was built in order to allows the use of a network simulator in future works to represent the communications in a more realistic way.

5 SIMULATION SCENARIOS

In order to evaluate the proposed controllers four scenarios were designed, with two circuits - an Oval and a City circuit, presented in Fig. 6. Scenarios 01 and 02 present each controller feature, namely the bearing controller and the LAC, comparing the platoon safety performance with and without these controllers. Scenarios 03 and 04 presents a more realistic scenario, in a city circuit with and

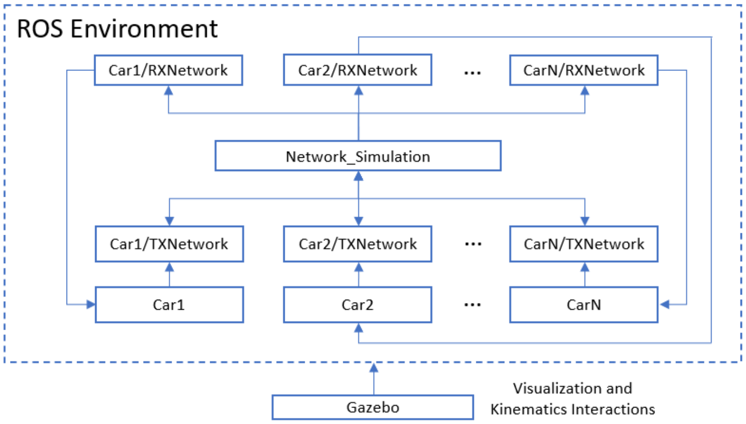

Fig. 7. Simulation Architecture

without obstacles. All the scenarios represent a full lap in the designed circuit, finishing with a braking action by the platoon leader, without any crash, as visible in the video presented in *https://youtu.be/Gjpg-yV0tDc*. The principal scenarios parameters are presented in table 2:

Table 2. Model Parameters

Parameters	Definition
Vehicles	4 to 11
Max Steering	0.52 rad
Safety Distance (SD)	5.5 m
Time Headway (T_H)	0.5 s
Leader Speed	50 Km/h
Longitudinal: K_P, K_I, K_D	2.0 , 0.005 , 2.0
Lateral: K_P, K_I, K_D	2.5 , 0.001 , 1.0
Time between Messages	0.03 s

5.1 Scenario 01 - Bearing test

The first scenario was designed to test the bearing adjustment of the lateral controller in an oval circuit. We performed a full lap with 4 SVs, with and without the bearing controller. The vehicles' path in each test is presented in Fig. 8. in this figure, it is possible to observe that even though with a similar trajectory, the vehicles without the bearing controller, does not follow exactly the same path in some parts of the circuit. The error is reduced in the curvature sections, but

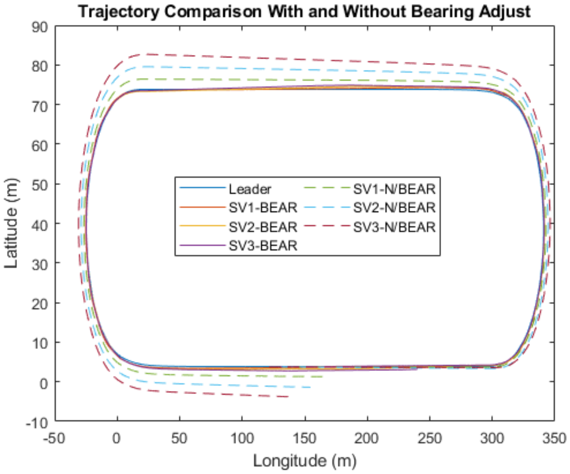

Fig. 8. Scenario 01 - Bearing Test

increases afterwards. As previously explained, this occurs because the heading of the $\theta_{e,i}(t)$ is near to zero, even with the cars in the wrong alignment. With the Bearing controller correction however, results are clearly much better, and the path of SVs is very close to the one performed by the Leader. In order to evaluate this performance, we can compare the average distance error for SV_3 in each test. Without the bearing controller, $\varepsilon_3 = 0.9863m$, while using the bearing controller, this error was reduced to $\varepsilon_3 = 0.4931m$, that indicates 50.01% improvement.

5.2 Scenario 02 - LAC

In order to evaluate the LAC performance, we carried out several laps with a 9 vehicles CoVP without the LAC. Then, we rebuilt the test using the LAC with a 11 vehicles CoVP. Figure 9 compares the trajectory of the vehicles in both situations in one lap. Without the LAC, where the SVs were able to follow the Leader, but with oscillations in the tail vehicles, namely in SV_6, SV_7 and SV_8. This oscillation is caused by the back propagation of the abrupt adjustments in the Leader's trajectories, which increases considerably with the number of vehicles in the platoon. The LAC, as depicted in fig. 9, deals with this problem, reducing the error propagation throughout the platoon and reducing the oscillation in the vehicles' trajectory. The LAC performance can be demonstrated considering the average distance error ($AVG(\varepsilon)$) in SV_8. Without the LAC, $AVG(\varepsilon_8) = 1.523m$, while using LAC, this error is reduced to $AVG(\varepsilon_8) = 0.7079m$. Another improvement provided by the LAC implementation is the possibility to increase the platoon size, given that the $AVG(\varepsilon_1 0) = 1.207m$, also reducing the error from the last vehicle in the test without the LAC in 16%.

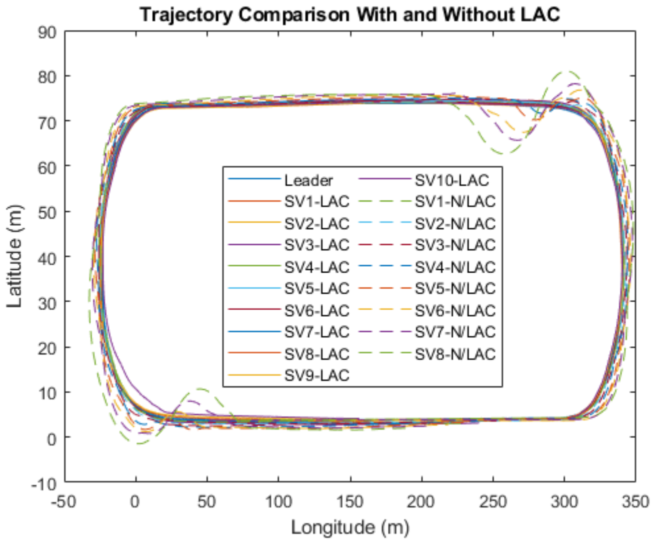

Fig. 9. Scenario 02 - Look Ahead Controller (LAC)

Comparing to the Leader, the lateral adjust in the last vehicles in each test also demonstrate the improvement provided by the LAC, as presented in Fig. 10, with a comparison between the SV_9 in the test without LAC and $SV_1 1$ using the LAC. It is possible to observe that $SV_1 1$ lateral adjusts are more smooth and have less oscillation in comparison with SV_9.

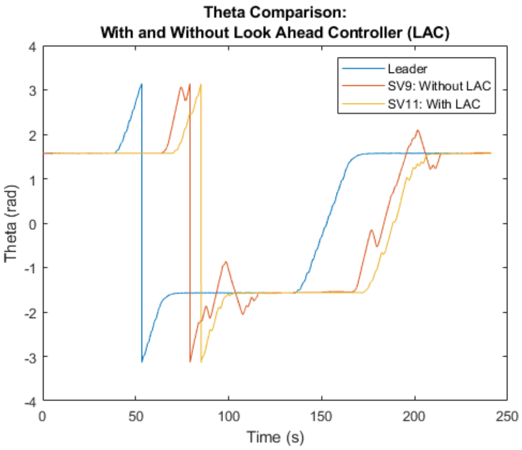

Fig. 10. Scenario 03 - Platooning curve performance

5.3 Scenario 03 - Complex Circuit

The CoVP is well defined and largely analysed in long straight roads, with easy or no curvature. However, more complex scenarios, with harder curvature, can cause oscillation and even instability in many controllers, decreasing the platoon's safety. In order to analyse our controller, using the longitudinal, lateral, bearing and LAC, we performed several laps with a platoon with 11 vehicles in the circuit of fig. 6, without obstacles. This circuit presents some interesting challenges, namely the different direction curves, straight sections and a quite hard bend.

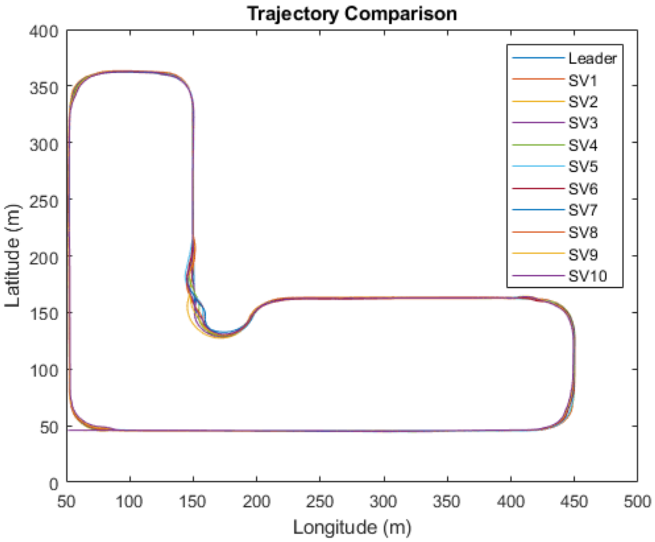

Fig. 11. Scenario 03 - Vehicles Path

The vehicle's trajectory is presented in Fig. 11 and demonstrated in the video in *https://youtu.be/Gjpg-yV0tDc*. All the SVs were able to closely copy the same path as of leader, with just a small oscillation in curve 4. Figure 12 shows the average error between the desired distance of SV_i and SV_{i+1} during the lap. As this distance never gets close to the defined SD, the platoon's safety is guaranteed, thus avoiding any collisions between the vehicles. Fig. 12 also demonstrates that the average error of the vehicle's distances is close to zero, although it varies in different situations, like curves. However, even with those changes, the errors are reduced after the curves. In the selected scenario, the local stability of the platoon cannot be guaranteed by the strict criteria proposed in 2, since $\varepsilon_4/\varepsilon_3 > 1$, for instance. However, the *global* stability of the platoon can be guaranteed, since $\forall \varepsilon_i/\varepsilon_1 < 1$, for $i > 1$.

5.4 Scenario 04 - Obstacle Avoidance

To further push the limits of the CoVP controller, in this last scenario we included a slalom section. The Leader uses sonars to avoid 14 vehicles distributed in the circuit, as presented in Fig. 6. The path carried out by the vehicles is depicted in Fig. 13, where the blue circles indicates the track obstacles. Again, it is possible to observe that all the SVs closely copied the same path as the Leader, even with the many and quick shifts in orientation. A presentation of

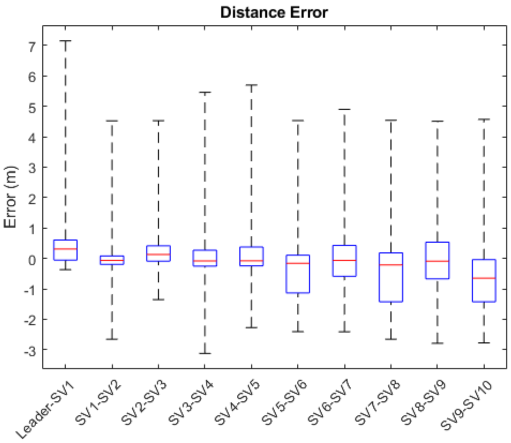

Fig. 12. Scenario 03 - Vehicles inter Distances

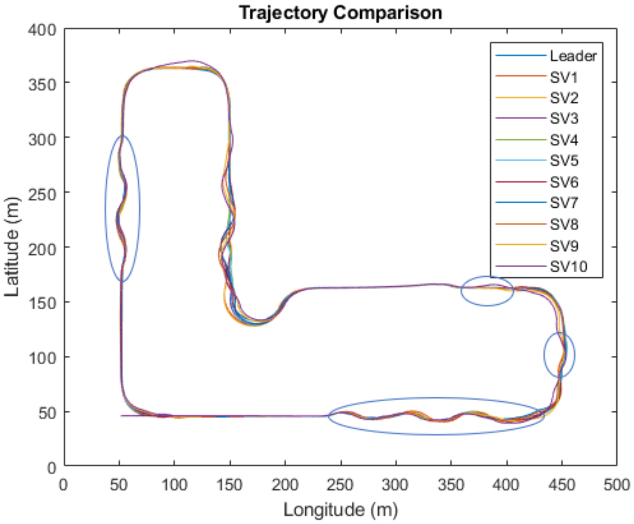

Fig. 13. Scenario 04 - Vehicles Path

this scenario is given in *https://youtu.be/4ysgAFnvWpI*. In Fig. 14 it is possible to observe that even with these imposed oscillations of the Leader, the mean of the distance errors of the platoon vehicles is close to zero. However, it is also possible to observe that SV_{10} gets closer to SV_9, since the distance error increases in the negative way. This means that as the vehicles perform closed curves in sequence, the SV_{i+1} are getting closer tho the SV_i, decreasing the platoon's safety. This occurs because the desired speed is constant. So, in a sequence of turns in different directions, while the SV_i linear speed decreases, SV_{i+1} linear speed is bigger, reducing the distance between the vehicles.

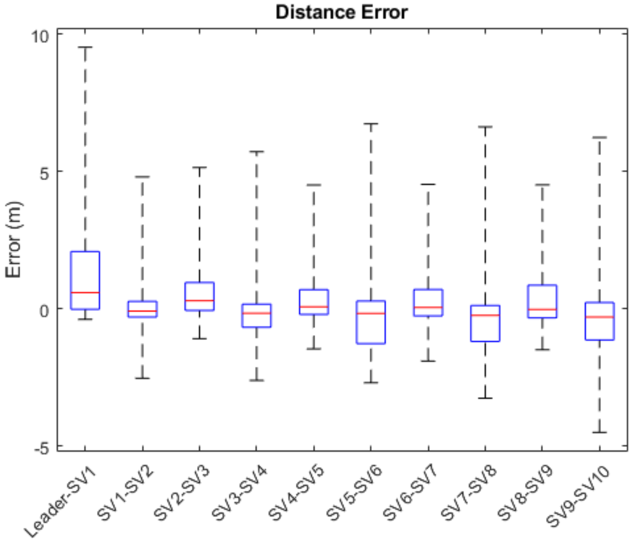

Fig. 14. Scenario 04 - Vehicles Inter Distances

Since the Leader reduce it's linear speed in curves 3 and 4, this effect is propagated through the platoon. Even with this approximation, none of the vehicles have come near to the SD. It is also possible to observe that the global platoon stability was guaranteed. This scenario also demonstrates the importance of having the lateral controller working together with the bearing adjust mechanism, in order to avoid collisions.

The platooning efficiency in this scenario also can be evaluated by the distance that the vehicles pass from the obstacles. In this case, the safety distance to the obstacles was defined as $0.5m$. The minimal, maximum and average distance between the vehicles and the obstacles are show in Fig. 15. This one also demonstrates that the average distance between the vehicles in the platoon to the obstacles is almost the same, which shows the efficiency of the algorithm and the ability of the vehicles to follows the leader's path.

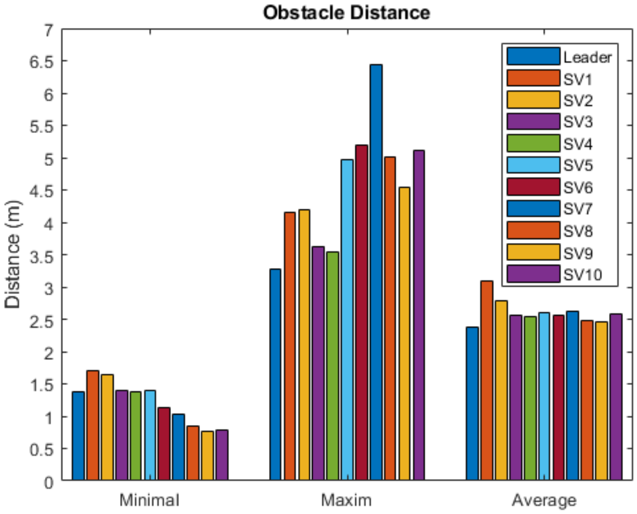

Fig. 15. Scenario 04 - Obstacles Distances

6 CONCLUSIONS AND FUTURE WORK

In this work, we presented a V2V-enabled Look Ahead PID controller, together with a method to reduce the disturbance propagation in the platoon. The proposed platooning controller also implements a solution to solve the cutting corner problem, keeping the platooning alignment. We evaluated the performance of these mechanisms over a robotics simulator, showing that this low complexity V2V-enabled CoVP controller can be effectively implemented and its maintains its stability under several different and challenging scenarios.

The bearing adjustment mechanism and the LAC were shown to be most important to increase the stability and decrease the lateral error along the platoon, mitigating the cutting corner problem and the disturbance propagation. We believe this controller can indeed represent an excellent stepping stone towards further research, particularly to support further investigations on the communications' impact in CoVP applications. These controllers were analysed in this work under several conditions, increasing the challenges and showing the controller reliability.

The implementation of an integrated controller for the platooning based purely in V2V communications avoid some costs like the necessity of any change in the infrastructure of the road, demanding only the presence of an On Board Unity in order to transmit the measured data between the vehicles. However, the analysis about the packet loss impact should be implemented as a future work. The implemented architecture was designed in order to facilitate integration with an network simulator, like OMNET, using the ROS.

As future work, we will extend the analysis of these CoVP control mechanisms to analyse the communication's impact over the CoVP controller, in particular the effect of delays and additional traffic upon the CoVP behavior. We also aim to compare the current controllers with a machine learning approach, using reinforcement learning.

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