MobMod Lab 3 report

Marco Sorbi
EURECOM
Antibes, France
marco.sorbi@eurecom.fr

Gabriele Spina
EURECOM
Antibes, France
gabriele.spina@eurecom.fr

This laboratory deals with the behavior of platooning mechanisms (CACC) and the impact of various CACC algorithms related to flow changes, and makes use of the SUMO simulator and PLEXE. We will analyze the differences between the main platooning algorithms and how they behave in case of perturbations.

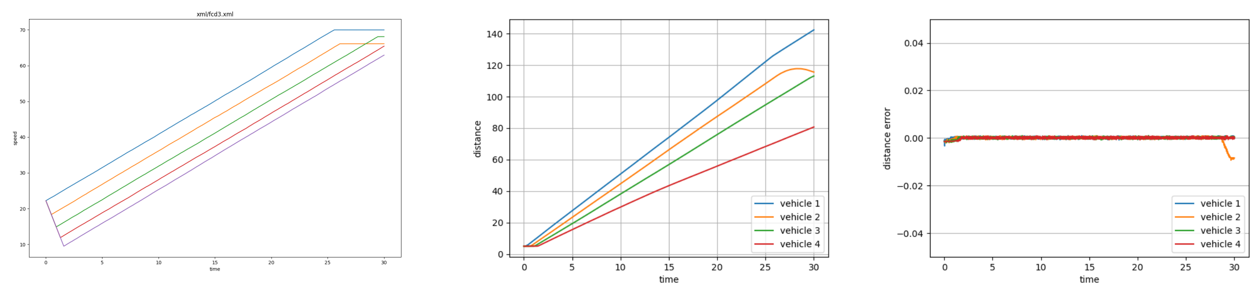
I. Controllers comparison

The goal of this task is to compare four platooning algorithms in a standard platoon mobility:

- **DRIVER**: car driven by default Car Following Model (Krauss).
- **ACC**: Adaptive Cruise Control, adapts the speed to maintain a fixed gap, measured by a radar.
- **CACC PATH**: Cooperative ACC, aims at keeping a fixed gap through inter-vehicular cooperation.
- **CACC PLOEG**: aims instead to maintain a fixed time-headway between vehicles.

A. Simulation 1 (DRIVER)

Fig. 1b shows that the inter-vehicular distance increases as time goes by. At the beginning, it increases because all the drivers, except the first one, decrease their speed, as shown in Fig. 1a, because they are too close to the preceding vechicle. The inter-vehicular distance error, shown in Fig. 1c, is computed with the formulas in Appendix III, taken from the Krauss model.

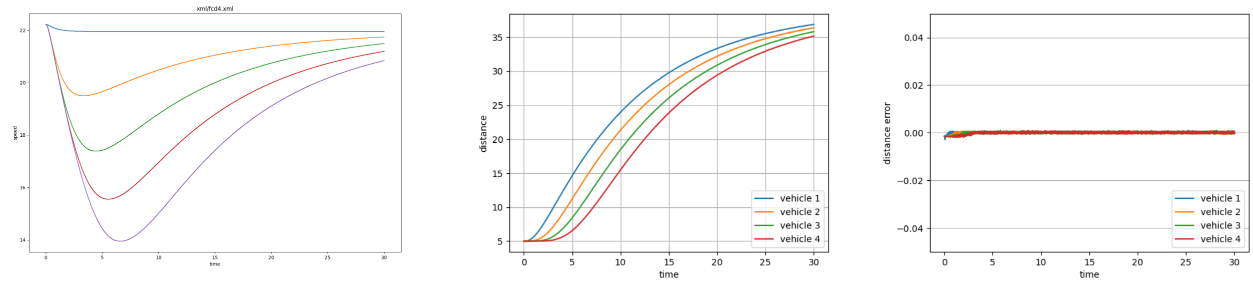


(a) Speed (b) Inter-vehicular distance (c) Inter-vehicular distance error

Fig. 1: Human DRIVER analysis.
A vehicle's interdistance is the distance from the preceding vehicle, it is not reported for the leading vehicle.

B. Simulation 2 (ACC)

Since ACC aims at maintaining a fixed gap with respect to the preceding vehicle, the speed adjustment is made in a more smooth manner and the inter-vehicular distances converge to a value correspondent to the gap (roughly 35-40 meters).

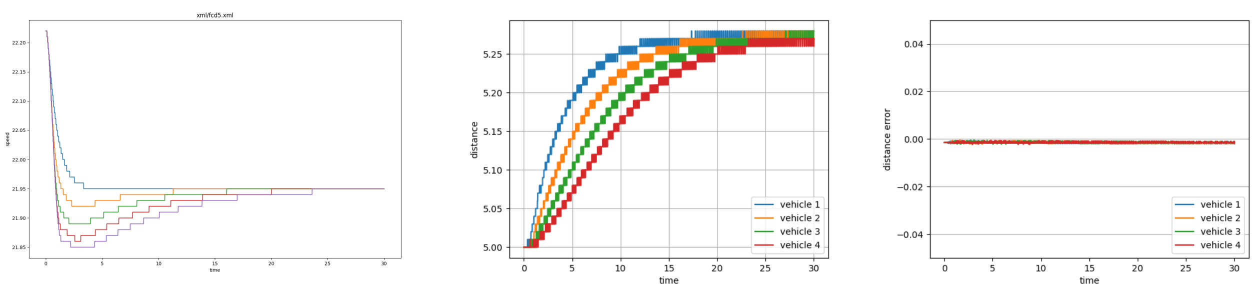


(a) Speed (b) Inter-vehicular distance (c) Inter-vehicular distance error

Fig. 2: ACC analysis

C. Simulation 3 (CACC PATH)

Since the vehicles cooperate with each other, they can afford a way smaller inter-vehicular distance to get a reduction of aerodynamic drag. In fact, when a vehicle breaks, it sends the information to the others, and there's no need to keep a big inter-vehicular distance as their reaction time is almost negligible and they will break all together almost at the same moment. This behavior is however risky: if the communication fails, for example for a sudden crash, also all the following vehicles are at risk, not having enough space to avoid the collision.

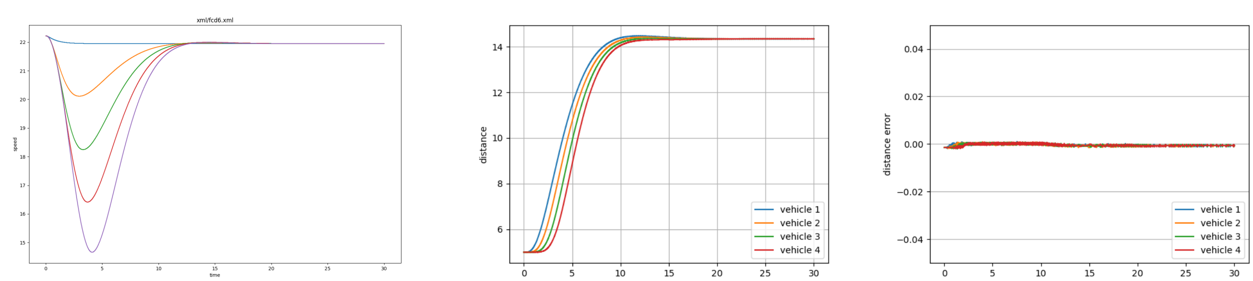


(a) Speed (b) Inter-vehicular distance (c) Inter-vehicular distance error

Fig. 3: CACC PATH analysis

D. Simulation 4 (CACC PLOEG)

The CACC PLOEG controller maintains a fixed time-headway between vehicles. At the beginning the vehicles slow down to reach the desired inter-vehicular distance, which increases with respect to CACC PATH as now it is almost three times bigger. It can be noted that CACC methods achieve a faster inter-vehicular distance convergence with respect to the ACC algorithm due to the cooperation between vehicles.



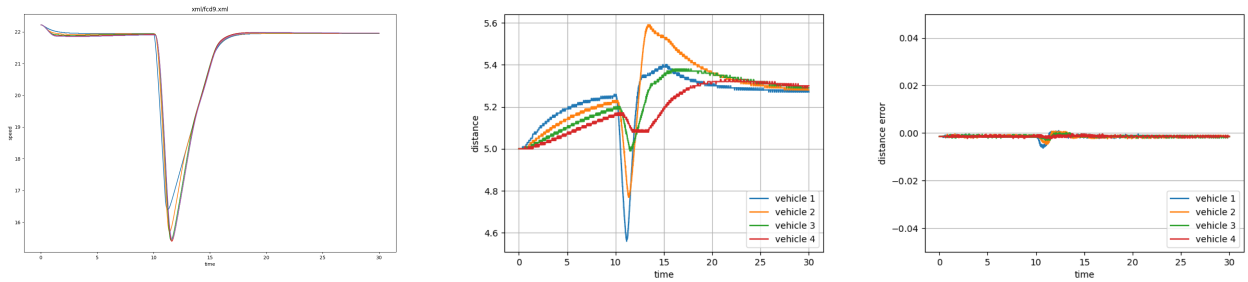
(a) Speed (b) Inter-vehicular distance (c) Inter-vehicular distance error

Fig. 4: PLOEG analysis

II. Flow perturbation

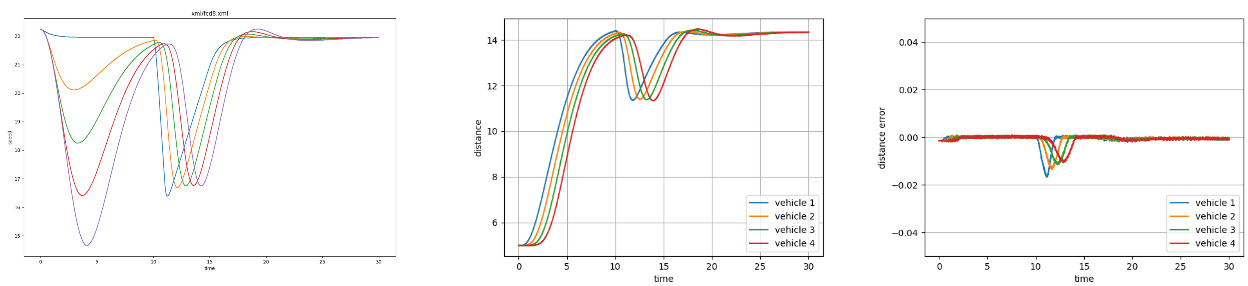
The goal of this task is to evaluate the effect of a flow perturbation on the platoon dynamics and to make a comparison between the behavior of CACC and PLOEG controllers. It is done by making the leader break at timestep 1000 and then accelerate again at timestep 1100.

The sudden breaking and acceleration of the leading vehicle cause a speed perturbation propagating through all the following vehicles. Fig. 5b shows that, although the inter-vehicular distances are very small, the PATH algorithm is able to maintain these distances in a safe manner, but it does so at the cost of a jerk way greater than the one in PLOEG, as shown in Fig. 6b, making the travel uncomfortable for human passengers. Moreover, with PATH the inter-vehicular distances varies in a messy way because every vehicle brakes in a different way, whilst with PLOEG they have the same variations as the vehicles act coherently.



(a) Speed (b) Inter-vehicular distance (c) Inter-vehicular distance error

Fig. 5: CACC PATH perturbation analysis



(a) Speed (b) Inter-vehicular distance (c) Inter-vehicular distance error

Fig. 6: PLOEG perturbation analysis

III. Appendix

For the calculation of the inter-vehicular distance error for the DRIVER algorithm we referred to the formulas used by the Krauss model. For the ACC, CACC PATH and CACC PLOEG algorithms, we assumed that they follow this model too. Starting from the formulas of the Krauss model referred to the desired velocity, equation (1) and equation (2), we computed the desired position using the uniformly accelerated motion of a vehicle which wants to reach a certain desired velocity. The acceleration that brings the vehicle to the desired velocity is therefore the one in equation (3), properly clipped to match the requirements on the maximum possible acceleration a and deceleration b, as in equation (4). Equation (5) is finally referred to the desired position of the vehicle, and equation (6) shows how to calculate its desired distance from the previous vehicle.

$$v_i^{safe}(t+\Delta t) = v_{i+1}(t) + \frac{\Delta x_i(t) - v_{i+1}(t)\tau}{(v_i(t) + v_{i+1}(t))/2 \cdot b + \tau} \tag{1}$$

$$v_i^{desired}(t+\Delta t) = \min\{v_{max}, v_i(t) + a\cdot\Delta t, v_i^{safe}(t+\Delta t)\} \tag{2}$$

$$a_i^{desired}(t) = \frac{v_i^{desired}(t+\Delta t) - v_i(t)}{\Delta t} \tag{3}$$

$$A_i(t) = \begin{cases} -b & \text{if } a_i^{desired}(t) < -b\,, \\ a & \text{if } a_i^{desired}(t) > a\,, \\ a_i^{desired}(t) & \text{otherwise} \end{cases} \tag{4}$$

$$x_i^{desired}(t+\Delta t) = x_i(t) + v_i(t)\Delta t + \frac{1}{2}A_i(t)(\Delta t)^2 \tag{5}$$

$$\Delta x_i^{desired}(t+\Delta t) = \Delta x_i(t) + v_{i+1}(t)\Delta t - \left(x_i^{desired}(t+\Delta t) - x_i(t)\right) \tag{6}$$

The following parameters, some taken from SUMO documentation [1], were used:

- $\tau = 1s$: reaction time
- $\Delta t = 0.01s$: timestep length
- $v_{max} = 70ms^{-1}$: maximum speed
- $a = 2.5ms^{-2}$: maximum acceleration
- $b = 2.6ms^{-2}$: maximum comfortable deceleration

References

[1] *Definition of Vehicles, Vehicle Types, and Routes - SUMO Documentation*. URL: https://sumo.dlr.de/docs/Definition_of_Vehicles,_Vehicle_Types,_and_Routes.html#car-following_models.