Homework 1 Report: Team 9
Adaptive Cruise Control Simulation

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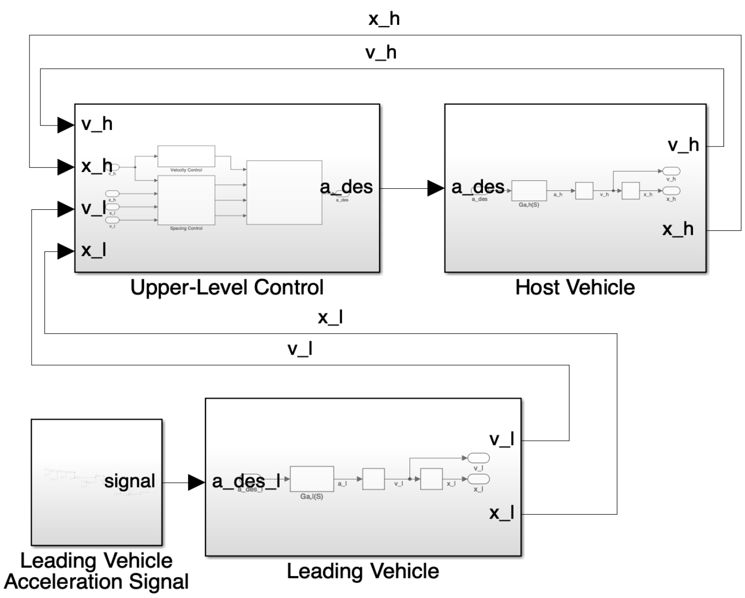
1. Introduction

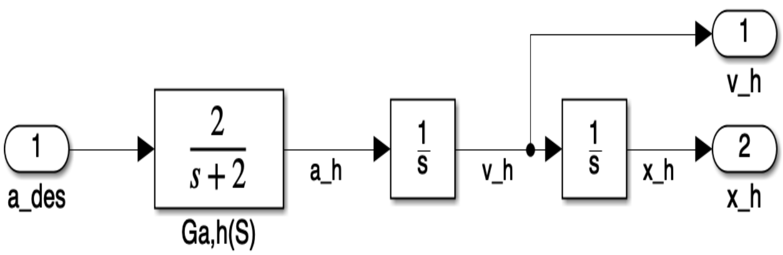
Scope of the homework is to design a Simulink model able to simulate a scenario in which a vehicle equipped with an ACC system would automatically manage the acceleration in response to the presence of another vehicle ahead. Once a desired time headway and a target speed are set prior to the simulation, we would expect the simulated ACC system to be able to automatically regulate the throttle and brake such as to both maintain the required distance from the leading vehicle and avoid collision, and to maintain the target speed in the case that the distance to the leading vehicle is large enough. Such speed variations are to be mild enough as to maintain a smooth driving experience. In order to assess the capabilities of the system, we built the model and simulated the described scenario.

2. Simulink model description

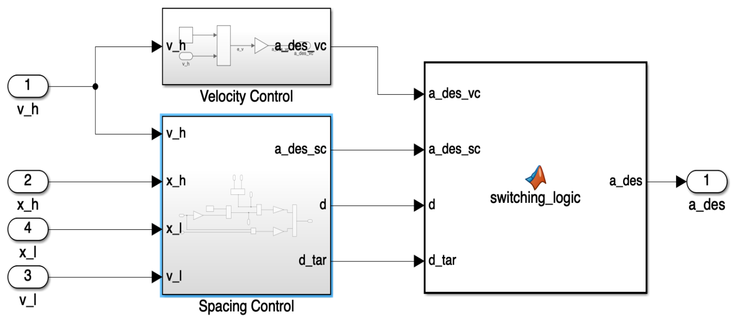


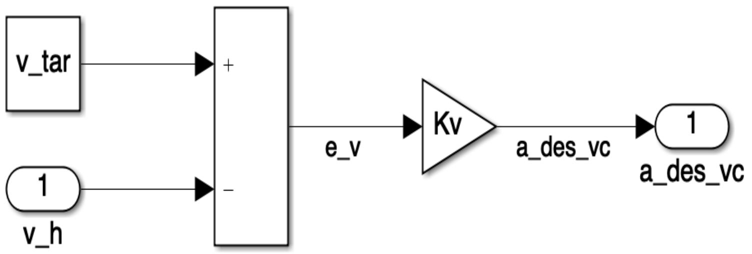
This is the most external layer of our simulink model.
It contains a part concerning the leading vehicle and another part relating to the host vehicle (the controlled one).
The leading vehicle block and the host vehicle block are described by a first order transfer function H(s) and they receive as input a desired acceleration signal. The output is the signal that represents the actual vehicle's acceleration. Thanks to a double integration we can obtain the velocity and the position of vehicles. This data is very useful for our purpose and in a real situation it would be obtained exploiting sensors.
The only two differences between the two blocks are the initial condition of the integrators and the desired acceleration signal: the leading vehicle receives a signal that is given a priori while the host vehicle receives a signal computed by the upper-level controller.

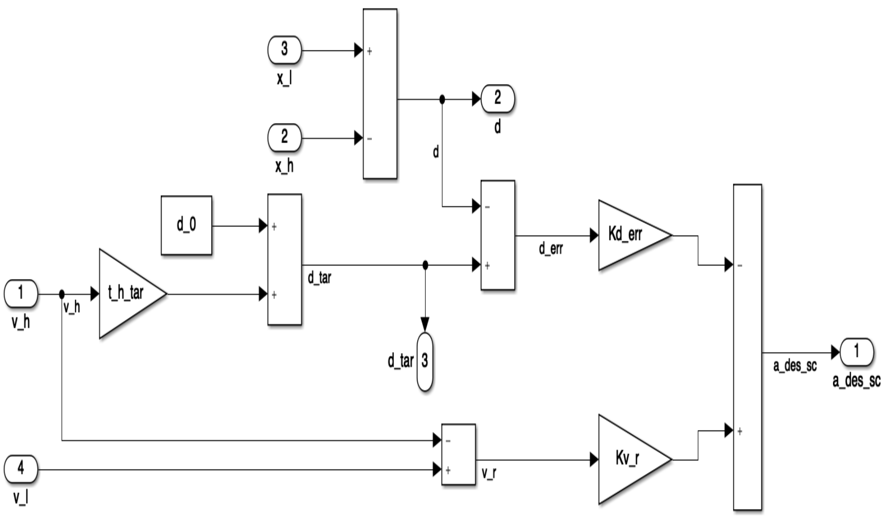
The picture on the right showcases the host vehicle



block (same for leading vehicle one).
The velocity and the position are given in output to be feedback to the upper-level controller. This controller has the aim to compute a desired acceleration signal for the host vehicle by switching to either the velocity control or the spacing control mode, each with different ways of computing the desired value: while the first one simply aims at maintaining a set speed in case of frontal clearance, the second one kicks in should a leading vehicle approach and aims at maintaining a certain distance from it depending on both the time headway the driver previously set and the speeds of the host vehicle.
Below is the upper-level control block with all its subcomponents: velocity control block, spacing control block and "*switching logic*" function.



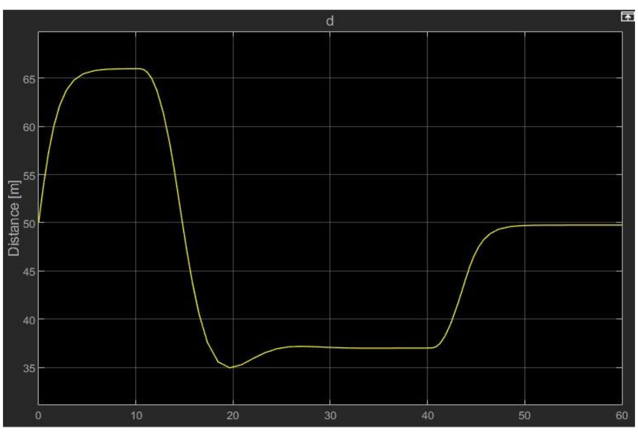


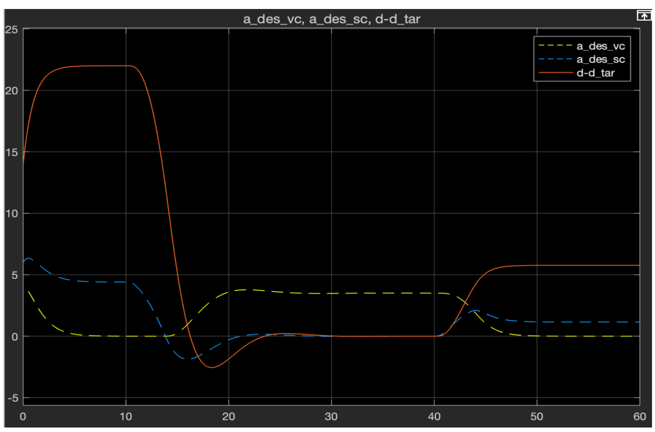



```
function a_des = switching_logic(a_des_vc, a_des_sc, d, d_tar)

if d > d_tar
    a_des = min([a_des_vc a_des_sc]);
else
    a_des = a_des_sc;
end

if a_des > 5
    a_des = 5;
end

if a_des < -3
    a_des = -3;
end
```

3. Graphs description

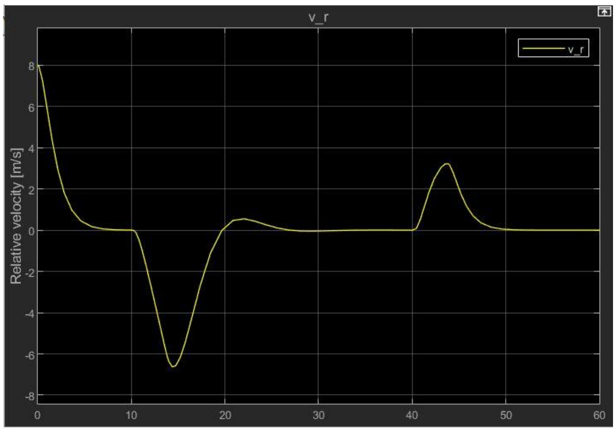
3.1. Distance between the vehicles





The first chart shows the value of the distance between the two vehicles throughout the simulation. We notice that for t=0s the distance is 50 meters as requested in the assignment. From second 0 to 10 we can see that distance between host and leading vehicles increases. In this phase, the ACC system is switched to velocity control, and the host vehicle speed is increased towards the target value (36 m/s). At about 5 seconds within the simulation, the slope of the curve decreases: the host vehicle has reached the target velocity.
At t=10.5 the leading vehicle starts to decelerate (-2 m/s^2) and as we expect the distance between vehicles decreases, since the host vehicle keeps the target velocity (36 m/s) that it reached in the previous seconds.
From second 14 to 20 the leading vehicle stops decelerating and starts keeping constant its velocity. The host vehicle will keep constant speed for a few seconds, until the desired acceleration value computed for the SC case is such that the ACC makes the switch to distance control, working at reducing the speed to match the one of the vehicle ahead.
From second 20 to 40 we can see that initially the distance between the two vehicles slightly increases and then remains constant as their speeds match.
At second 40 the leading vehicle accelerates for 4 seconds (2 m/s^2) and as a consequence we can notice that distance increases, until second 50 when the host vehicle reaches the same velocity as the leading one. Passed second 50, as we can notice, distance remains constant: the ACC system has switched back to velocity control, as the leading vehicle is not within the target distance from the host vehicle.
In the second plot we can see the values of the desired acceleration computed for both modes (SC and VC): due to the switching logic we implemented, the transition is being made in a way such that continuous switching is prevented. For instance, at t=14 the switch to SC is made because its desired acceleration value is the lowest one, even though the distance between the vehicles is higher than the desired one.

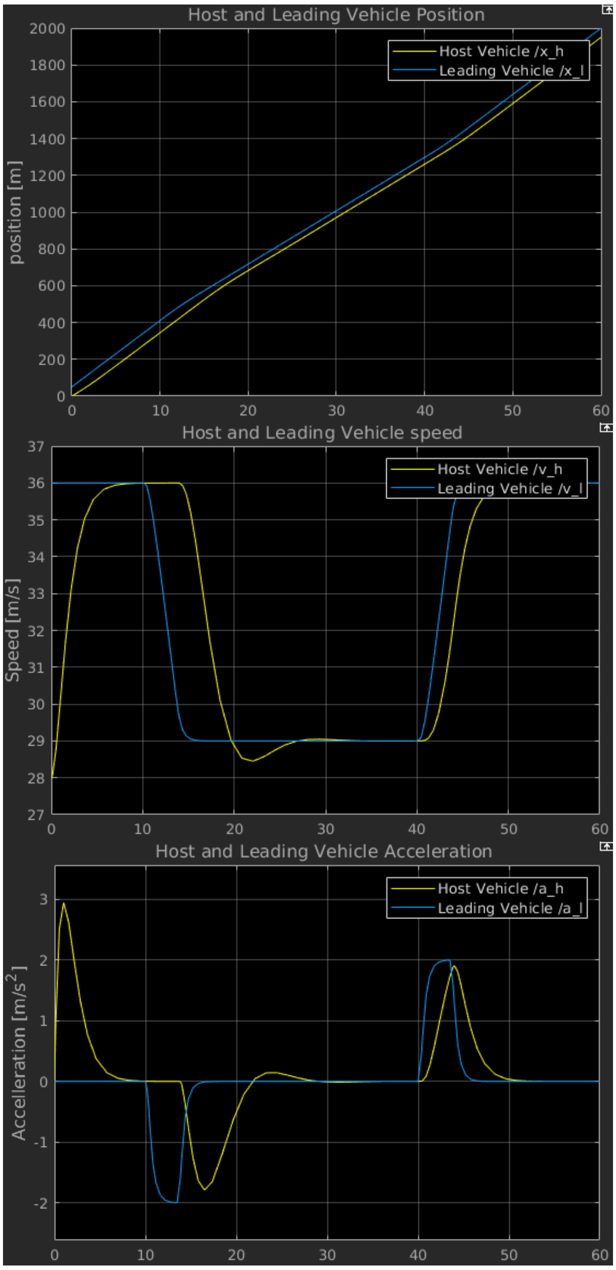
3.2 Relative Velocity



The course of relative velocity value during the simulation is interesting to analyze as well. The initial positive value is due to the leading vehicle being faster. Slowly the host vehicle catches on as the ACC works to increase the speed.
The sharp negative variation at t=10 is caused by the leading vehicle breaking, but the ACC is able to quickly react and slow down the host vehicle by matching its speed.

Finally, the bump at t=40 is a consequence of the leading vehicle's acceleration, and the ACC is able to switch to velocity control again and maintain the target velocity.

3.3 Position, Speed and Acceleration charts



These charts show the host and leading vehicle position, speed and acceleration values throughout the simulation.
As mentioned before, we can see how the host vehicle starts accelerating as soon as the simulation is started, being the ACC system in the velocity control phase and being the leading vehicle very distant.
As the leading vehicle breaks, the host vehicle keeps on and when the spacing control phase kicks in, it follows through reducing its velocity as well.

We can see how the acceleration trend of the leading vehicle is closely followed by the host vehicle. The larger delay that the host vehicle seems to have at slowing down in the first half of the simulation is to be attributed to the greater initial distance between them. Once the host vehicle catches up to the leading one, it’s able to react more quickly to the leading vehicle’s variations of speed.

4. Conclusion

The simulation result shows how the designed ACC system is able to correctly respond to the environmental information and apply the correct action in order to slow down the host in case of an approaching vehicle, as well as to increase its velocity given the necessary front clearance. Such variations are done promptly yet smoothly, and the final result is that the host vehicle is able to follow behind the leading one with no human intervention, and no risk of collision.