# Assignment 3 – Lane Keeping Controller

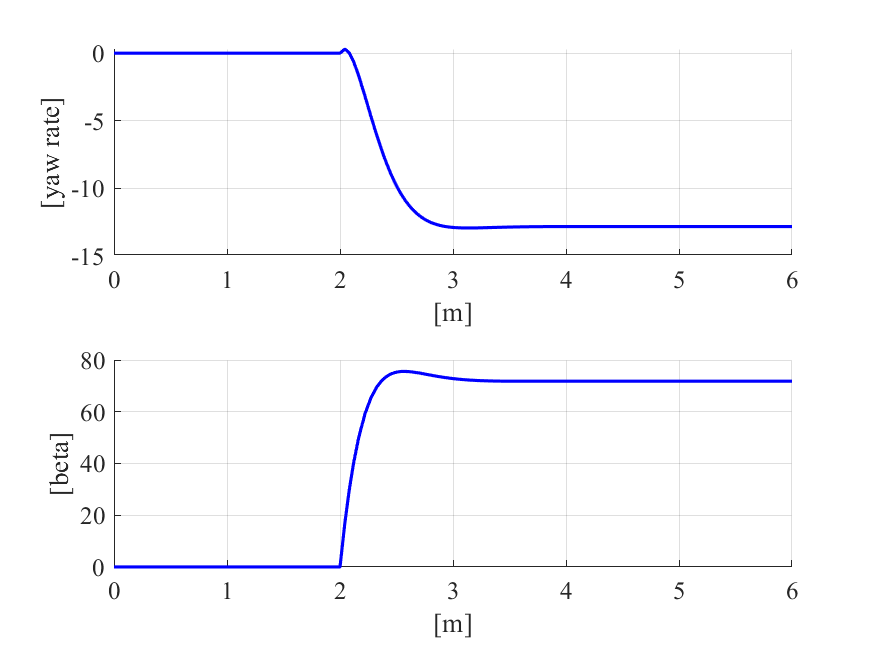
Matteo Gravagnone s319634, Danilo Guglielmi s318083

### Introduction

In this report we are going to submit main results of the implementation of a linear state feedback lane keeping / path tracking controller for a single-track model. In order to evaluate its performances due to different tunings, both pole placement and linear quadratic regulator approaches have been selected.

### Single-track model and its response

The formulation of our single-track model consists in a time-varying linear state space system with sideslip angle and yaw angle as states and several outputs are derived from the state variables in order to describe how the vehicle behaves in our tests. The time-varying property gives the possibility to carry out simulations even when the speed is changing in time by properly computing the state space matrices.

Preliminary analyses were carried out to evaluate vehicle response without control functionalities. This includes how the eigenvalues of the matrix A vary as a function of vehicle speed and the response obtained after apply a step-steering input. *Let’s note that our vehicle hasn’t rear-steering, so any input only affects the front-steering angle.* Immagine che contiene testo, Diagramma, diagramma, linea

Descrizione generata automaticamente

Figure - Step steering response Figure - Poles variation in function of vehicle speed

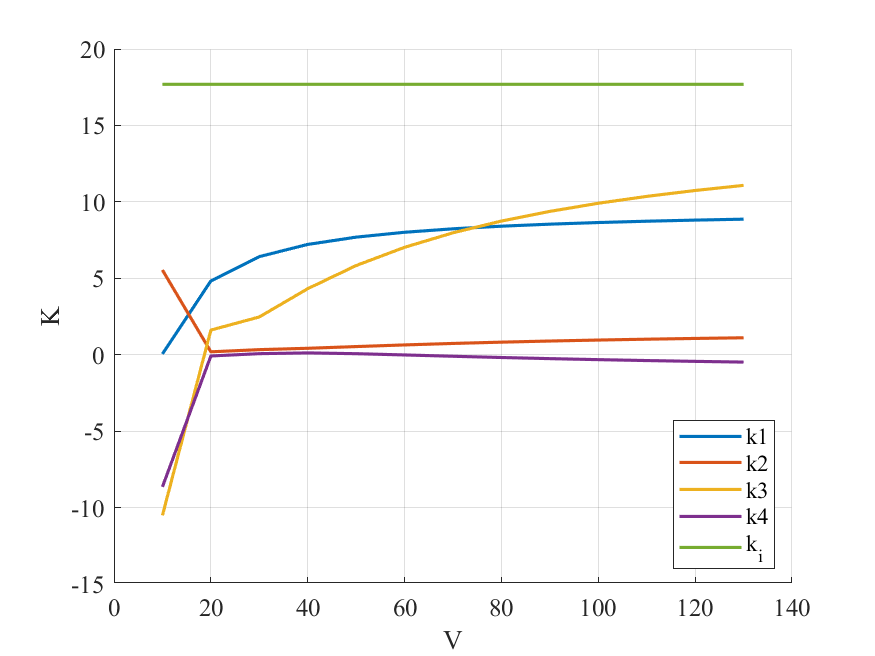
In Figure 1 there are highlighted the yaw rate and beta behaviours after a step ……….

In Figure 2, we can notice the poles variation in function of the vehicle speed that is progressively increased from 5 up to 130 km/h. As we can see the real part decreases in magnitude when the the vehicle speed is higher: the response of the vehicle becomes slower, while technically remaining stable. In addition, at about 16 km/h, the poles shift from purely real poles to complex conjugate with increased imaginary part: the system exhibits an underdamped behaviour.

### Linear state feedback lane keeping / path tracking controller

The structure of the controlled system resembles the one shown during lectures, so the control input, which is the steering angle, is given from the contribution of a feedforward term based on the curvature and a feedback term. This last contribution consists in both a proportional gain which multiplies the base state that is composed by the lateral error, heading angle error and their derivatives and an integral factor which only considers the integral of the lateral error. Furthermore, we have to point out that considering also the integral of the heading angle error leads to the uncontrollability of the entire system and was therefore not included in our extended state space formulation.

In order to tune the control gains, both pole placement and linear quadratic set-up were used. Both methods work on the extended matrices A and B of the lane keeping / path tracking problem. Independently from the tuning approach, look-up tables were built offline for different operating speeds as the controller should properly work even when the dynamics of the system change as shown in previous paragraph.

Immagine che contiene linea, Diagramma, diagramma, testo

Descrizione generata automaticamente

Figure - Gain variations with a Pole Placement approach Figure - Gain variations with a LQR approach (Q=diag([1..1]), R = 1)

### Conclusion

The model the team built captures multiple elements that characterize the longitudinal behaviour of passenger cars and, in specific aspects, electric cars. It is noteworthy that, despite many simplifications that we highlighted in this report, the process required the comprehension of the items, both in the ideal and real case, and the proper interaction among them.