Question: do we need a D term in the steering angle PID controller ? Do we need to avoid an I term ? What are the impact of these on the balancing control loop ?

Reason for the question: MDH uses a PD controller (P=0.10 ; D=0.04). As of 26/11/2019, our controller is a PI (P=30 ; I=30).

Plan :

* Write equations for the balancing control loop in steady-state. Compute the gains from disturbances to true steering angle. Is a D or I term needed/should be avoided ?
* Confirm in simulation.

Conclusion : The equation giving the true steering angle as a function of reference roll, reference steering angle and steering angle disturbance does not contain the PID transfer function, therefore the choice of PID gains has no impact during steady-state.

# Bike model

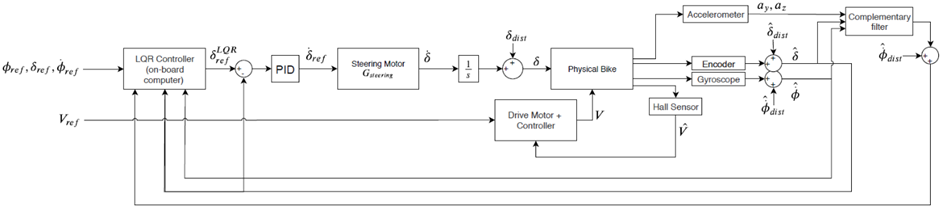


Figure - Block diagram of the balancing control loop

The transfer functions of each component of the bike are :

* Steering motor :
* Steering angle PID controller :
* Bike :
* LQR :
* Encoder :
* Gyroscope :
* Hall sensor :
* Accelerometer (accelerations on y and z-axis noted as and ; see Umur ERDINÇ’s thesis page X-XI, Eq. A.16-A.17) :

The roll angle can be calculated from accelerations as follows :

Linearizing leads to :

Measurements can be used to obtain an estimate of the roll angle from accelerometer data. This estimate is noted and is computed as follows :

Finally, replacing and by their expressions given in Eq. and approximating the function for small angles, we obtain :

Using Laplace tranform :

* Complementary filter :

# Steady-state response

In steady-state (), the transfer functions presented above reduce to :

The measured quantities can be written as :

The roll rate reference is always equal to zero for balancing, therefore :

Using the block diagram in Figure 1 and Eq. , we can write :

Using the block diagram in Figure 1 , we can write :

Taking in Eq. and Eq. and using the fact that from Eq. and , we get :

As we consider the case where the bike is balanced, we have :

is computed from as :

Substituting Eq. , and in Eq. leads to :

Substituting Eq. , and in Eq. leads to :

Substituting Eq. in Eq. , reorganizing and simplifying, we obtain :

Simplifying further :

Finally, we obtain :

The steering angle in steady-state does not depend on the gains of the PID.