TÉCNICO LISBOA

Computer Control

Lab Project

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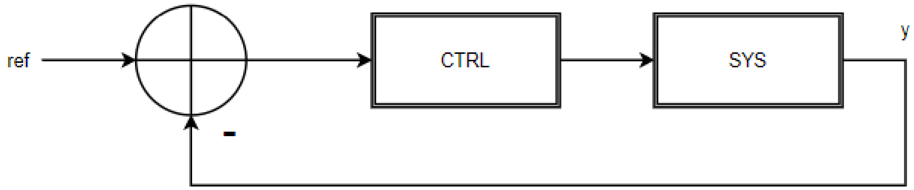
Feedback Control System

Design Approach



The work was divided in two steps the Design of the System and the Validation both are interconnected because the objective is to get the best performance and make decisions will suit best to the final propose to control the flexible control bar joint.

Designing the System:

1. Design the regulator (LQR)
2. Design the observer (LQE)
3. Merged regulator and observer (LQG)

Validating the System:

1. Validate the Regulator
2. Validate the Observer
3. Validate the Merged
4. Add external input and test on real system

The Model used is the following:

$$x(k+1)=Ax(k)+Bu(k)$$
$$y(k)=Cx(k)+Du(k)$$

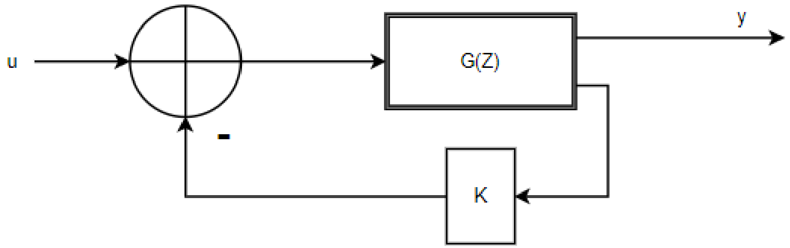
$$A=\begin{bmatrix} 5.1367 & -11.4974 & 14.4767 & -10.8271 & 4.5285 & -0.8174 \\ 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \end{bmatrix}$$

$$B=\begin{bmatrix} 1 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}$$

$$C=\begin{bmatrix} 0 & -8.5643e^{-5} & 6.3985e^{-4} & -6.0321e^{-4} & 0 & 0 \end{bmatrix}$$

$$D=0$$

LQR (Linear Quadratic Regulator)



The aim of the LQR controller is to find the poles in order to minimize the function cost:

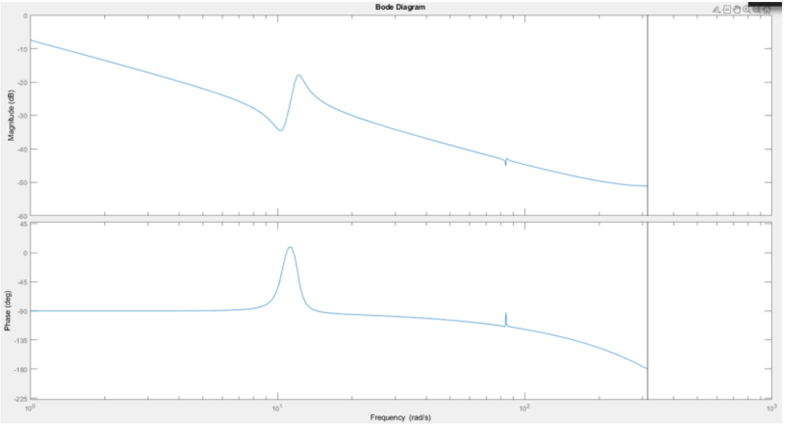
$$J(k) = \sum_{k=0}^{\infty} \left(x^T(k)\, Q\, x(k) + R\, u^2(k) \right)$$

Q and R are called tuning knobs.
The effect of increasing one of these parameters is the same to decrease the other one.

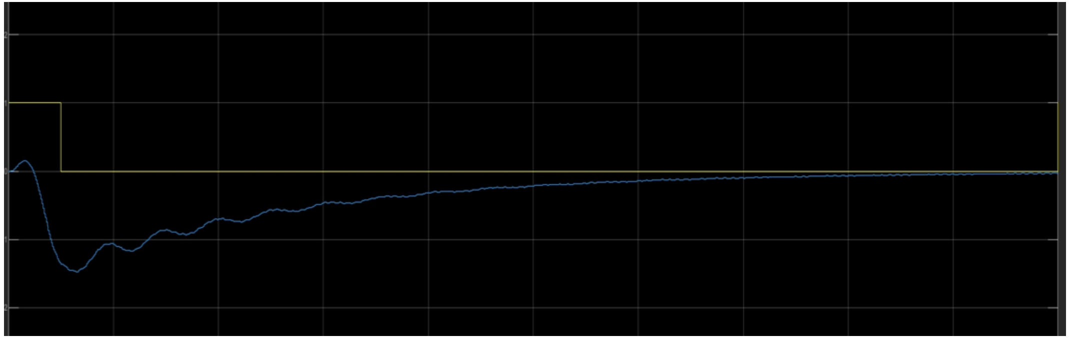
LQR (Linear Quadratic Regulator)

Increasing the weight R:

- ❖ Decreases the amplitude of u (Good);
- ❖ Increases the response of y to disturbances (Bad);
- ❖ Reduces the closed-loop bandwidth:
  - Makes the system slower (Bad)
  - Reduces sensitivity to high-frequency noise and model errors (Good)

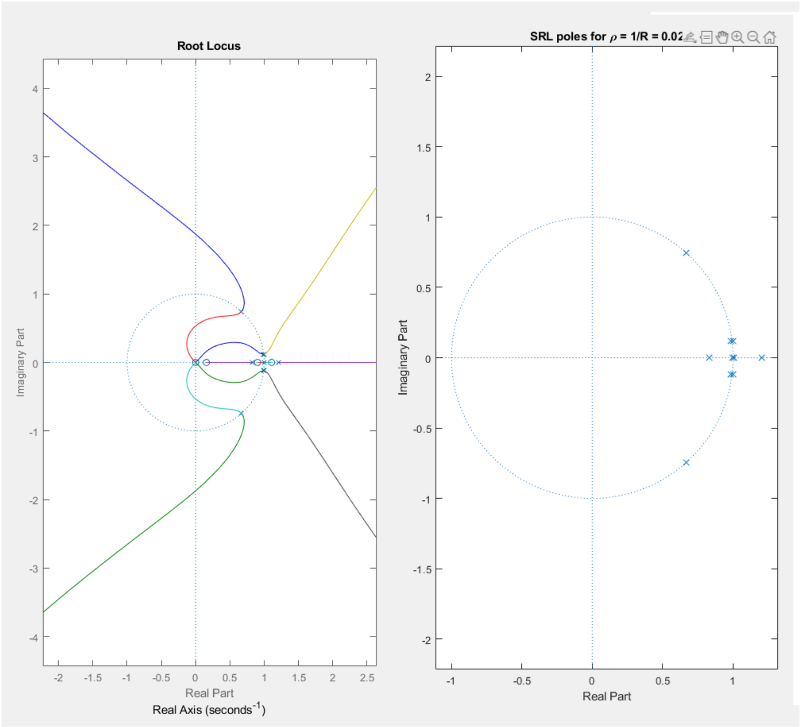


Frequency Domain R=50

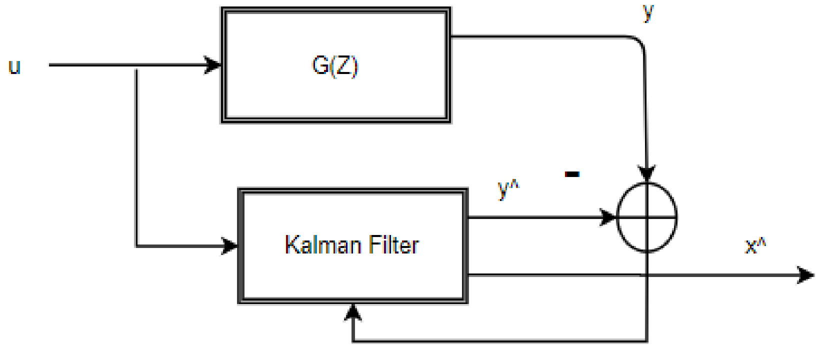


Time Domain R=50

LQR (Linear Quadratic Regulator)



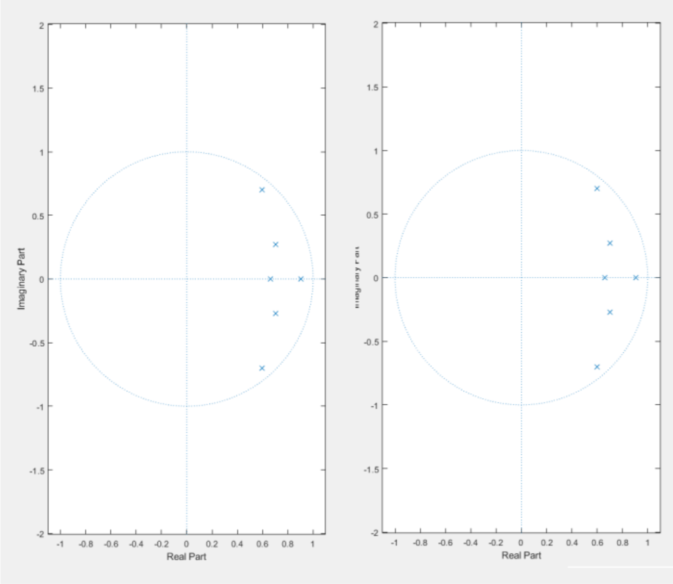
LQE (Linear Quadratic Estimator)

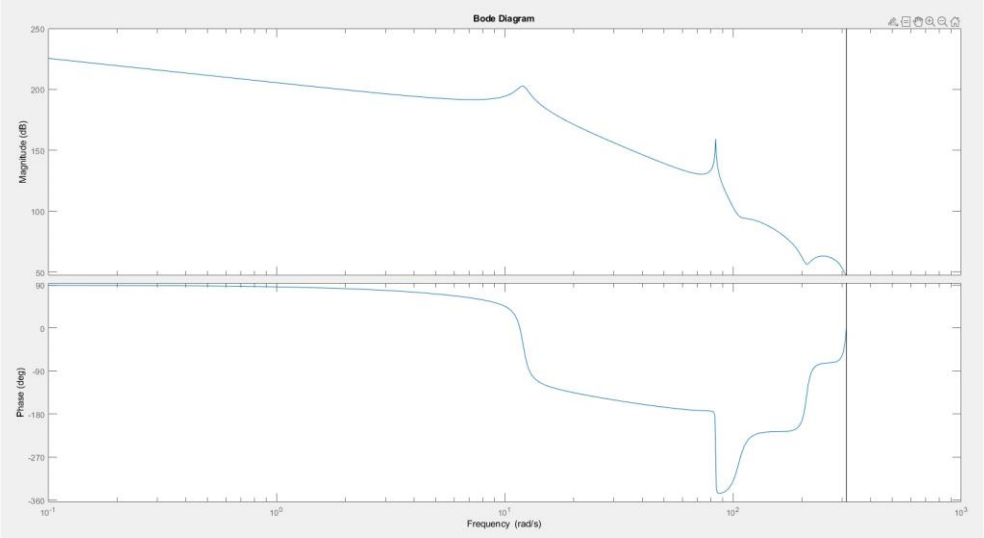


At this step we used the kalman filter to estimate the plant state looking at the input and the output. It assumes the inclusion of noise inputs.

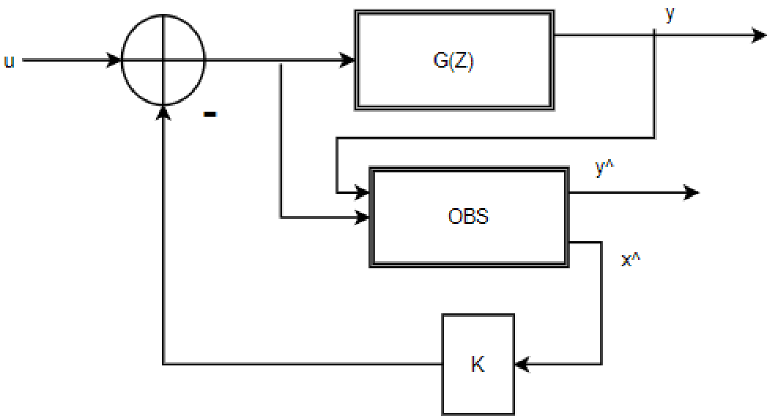
$$x(k+1)=Ax(k)+Bu(k)+w(k)$$
$$y(k)=Cx(k)+Du(k)+v(k)$$

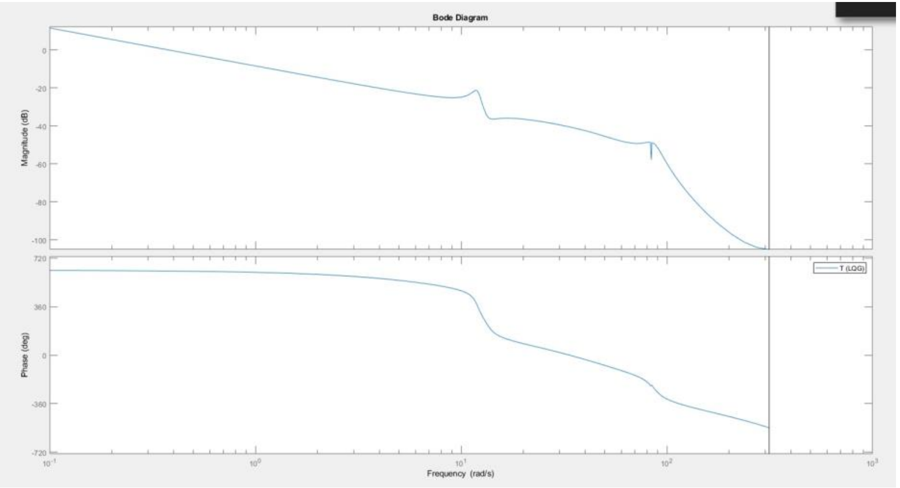
LQE (Linear Quadratic Estimator)





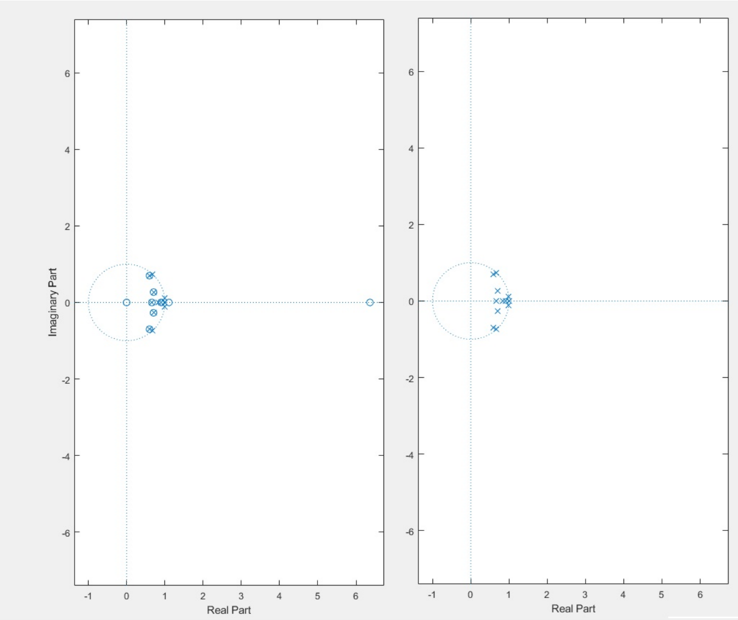
LQG (Linear Quadratic Gaussian)

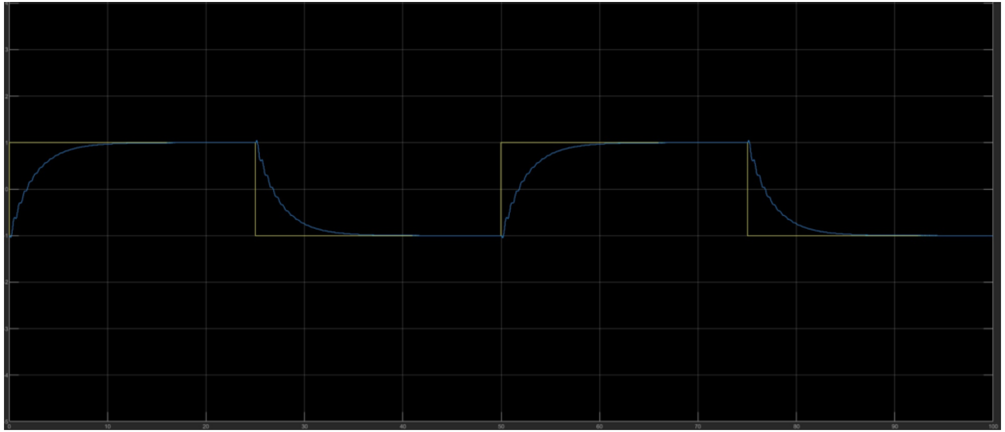




Frequency LQG Response

LQG (Linear Quadratic Gaussian)

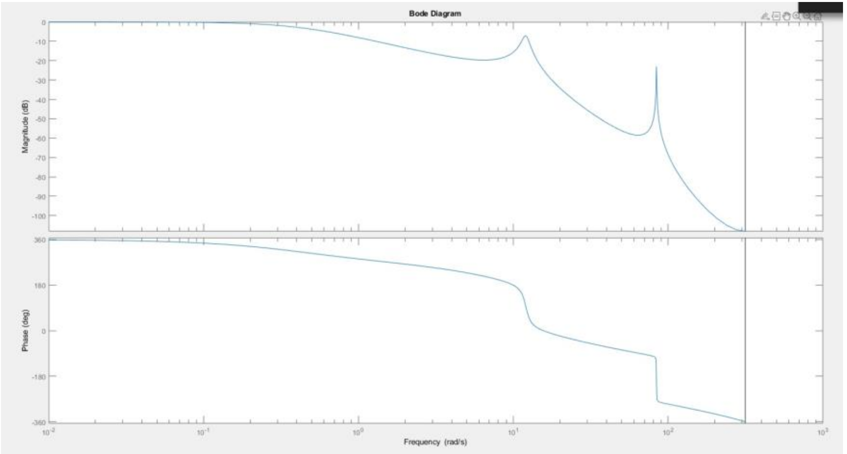




Time LQG Response

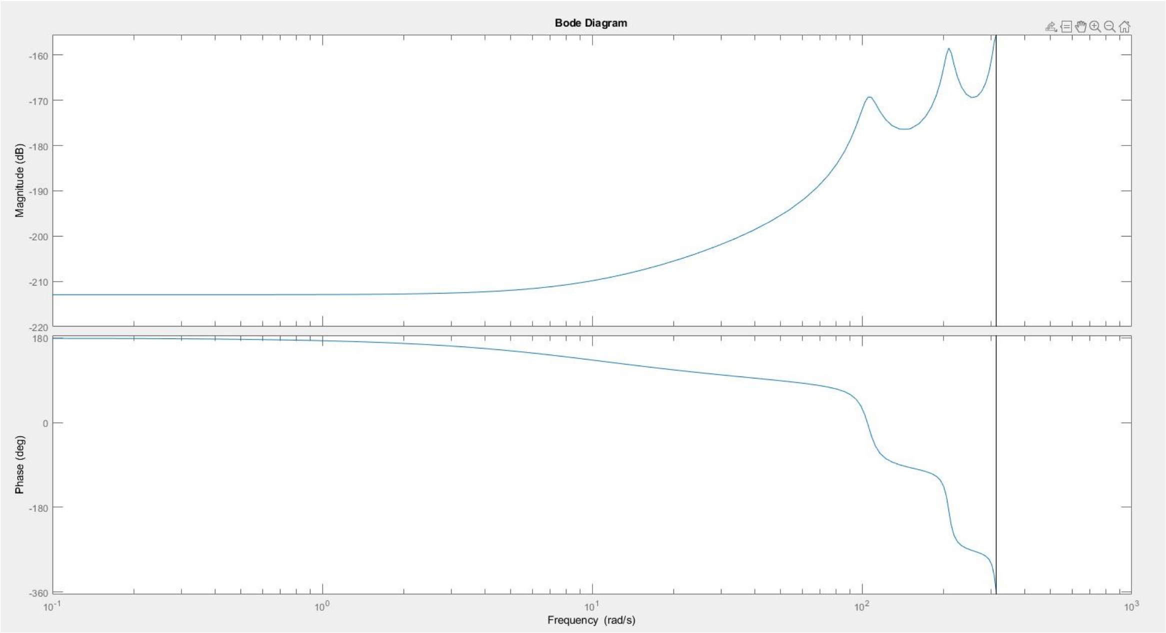
Effect of the inclusion of a pre-filter

The objective of the inclusion of a pre-filter is to ensure that we don't have undesirable behaviours on the system doing it by filtering and limiting some signals.



Pre-filter on LQR system

Since we cannot guarantee the reference tracking, it is necessary to recover the gain by changing the value of Nbar, in order to adjust the u(t) variable ensure that the output is equal to the reference



Pre-filter on LQE system

Performance analysis and limitations

we do some tests with different values of R in order to choose the one which can provide the best behaviour in our plant, so that it can guarantee a better bar control. We realized that for high values of R, the system is slow and it follows the reference, and this because the manipulate variable varies very slow. Better saying, the bar needs a larger time interval in order to reach the desired position. For low values of R, the system is faster and have an oscillate behaviour, which can cause some instability. Since we're dealing with real system, and we are exposed to the existence of noise and physical limitations, this instability for small R can be provoked by the increasing of the bandwidth which makes the system subject to the effects that hadn't been modeled.

Conclusions

After the test performed in the lab we can concluded that the designed controller was with success, with the junction of different controllers we were able to produce one system controller. To get this good controller of the system was very important to tune R value to get an compromise between the faster or slower response controller that could perform at it best to control the system.