

Additional Questions

Robot Control

Performed at the:
University of Applied Science Carinthia



University course: Systems Design

under the guidance of:
Andrjia Rojko

by

Tobias Karg Bsc.

Studentnumber: 1110527027

Contents

List of Figures	II
1 Control Behavior of CT-Controllers	1
2 Additional notes to CT-like Controllers	2
3 Additional notes to CT-like Controllers	4

List of Figures

2.1	Controller overview of Computed Torque controller	2
2.2	Controller overview of Computed Torque like controller with gravity compensation	2
3.1	Controller overview of Computed Torque controller	4
3.2	Controller overview of Computed Torque like controller with gravity compensation	4

1 Control Behavior of CT-Controllers

This chapter will evaluate the behavior of the CT-Controller in regards to its error dynamics and will explain, why this behavior is expected.

Since the concept behind the CT-Controllers can be summarized to: Linearize the system to obtain a double integrator and control this one, the double integrating system will be taken into consideration.

$$\begin{pmatrix} \dot{e} \\ \ddot{e} \end{pmatrix} = \begin{pmatrix} \mathbf{0} & \mathbf{I} \\ \mathbf{0} & \mathbf{0} \end{pmatrix} \begin{pmatrix} e \\ \dot{e} \end{pmatrix} + \begin{pmatrix} \mathbf{0} \\ \mathbf{I} \end{pmatrix} \mathbf{u}$$

This system is describing the error dynamics. All other model parts of the model have been removed from the control task by the usage of the computed torque controller. Since the controller is only simulated and the model is taken to be perfect, the usage of the computed torque controller does not provide any disadvantages in regard to control performance.

If the system itself, so without its input, is analyzed, it can be seen, that the error dynamics have a double pole within the origin. By using the controller with critical damping, the parameters $k_p = 100$ and $k_d = 20$ are obtained. Using this parameters the poles of the error system are shifted to:

$$\text{eig}(\mathbf{A} - \mathbf{kB}) = \text{eig}\left(\begin{pmatrix} 0 & 1 \\ 0 & 0 \end{pmatrix} - \begin{pmatrix} k_p & k_d \end{pmatrix} \begin{pmatrix} 0 \\ 1 \end{pmatrix}\right) = \begin{pmatrix} -0.5 \\ -39.5 \end{pmatrix}$$

This eigenvalue are showing that the error system is asymptotically stable and will drive the error and its derivation to zero. So it can be said by using the a proper set of gains the error of the system will always approach zero.

The initial position errors can explained by two points:

- The seconds joint's reference is a cosine signal, therefore the initial error cannot be zero.
- The velocity of the joint has to be taken into account. The velocity error itself has not been displayed in the report. Since the double integrator has to states, which the controller should drive to zero, the position error will show an amplitude, even though the initial position error might be zero.

The controller which is used here consists only of a proportional and a differentiating term. This type of controller is prone to distortions and does not provide a specific robustness against these distortions. If the simulations are done with some unmodeled distortions e.g. a constant additional torque in each joint. This needed robustness can only be created by an integrating term within the controller.

2 Additional notes to CT-like Controllers

This chapter will provide some additional remarks to the computed torque like controllers with gravity compensation, which can be seen in figure 3.2. This controller has, compared to the computed torque controller in figure 3.1, only the gravitational term in the linearizing component.

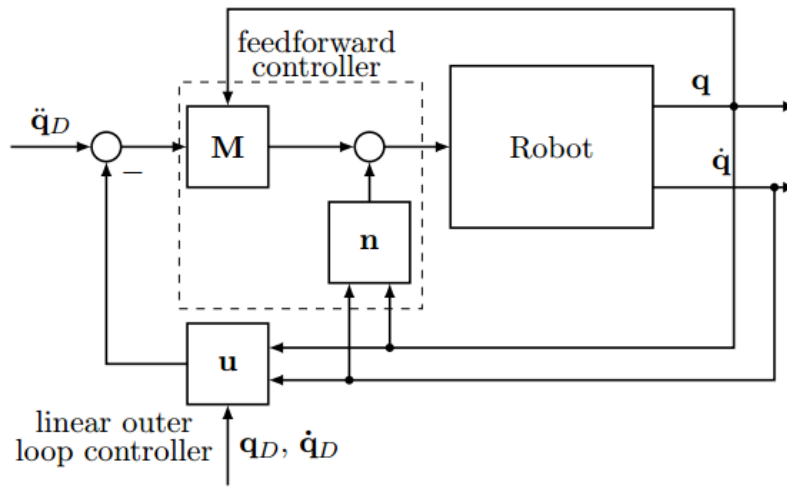


Figure 2.1: Controller overview of Computed Torque controller

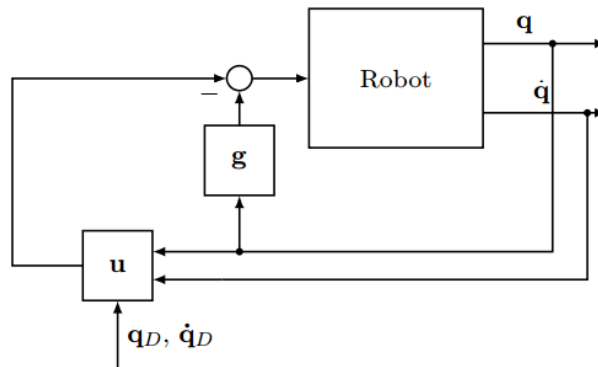


Figure 2.2: Controller overview of Computed Torque like controller with gravity compensation

This type of controller has shown good behavior, even though there have been a lot of simplifications within the design process. The terms which have been excluded are

the inertia term and the centrifugal/coriolis part. If the application or the architecture of the robot is chosen, so that the excluded terms have almost no influence of the final dynamics, this approach become even more suitable. An example for such a layout/application is a robot arm which is not moving a lot, and is controlling for a steady state position most of the time. In this case the centrifugal term becomes irrelevant and since the robot does not see a lot of acceleration the inertia term can also be ignored.

Comment to the PD Control within figure 3.6 (p.17): The proper tracking of the reference with the aggressive parameter set is bought with unrealistic high torque vales. The peak for the first joint is around 250Nm. Values in this range does require huge motors and might even be higher then the mechanical stability of the robot arm, which is by given as a lightweight one.

3 Sampletime related issues of robot control