1 INTRODUCTION

The Quanser HIL Driving Simulator (QDS) is a modular and expandable LabVIEW model of a car driving on a closed track. The model is intended as a platform for the development, implementation and evaluation of a variety of control systems. The QDS consists of a variety of components that are integrated together to create a representation of a vehicle being driven on a track. One possible configuration is shown in Figure 1.1. The model utilizes the Quanser Rapid Control Prototyping Toolkit (RCP) to facilitate hardware-in-the-loop interfacing (HIL). The Quanser 3D Viewer is also used to create an immersive visual environment for testing and evaluating controllers. Students are expected to observe and think critically about the effects of system parameters on not just the discrete plant, but the overall system.

Some examples of the real-world control problems that can be addressed using the QDS include parking assist systems, radar guided cruise control, active suspension, traction control and autonomous navigation.

Figure 1.1: Quanser Driving Simulator

Topics Covered

- Basic data gathering using LabVIEW™
- PD speed control of a DC motor
- PI position control of a DC motor
- Autonomous vehicle navigation

Note: This workbook contains a single independent laboratory experiment as an introduction to the QDS platform. If you are interested in the complete QDS platform, please contact info@quanser.com

2 VEHICLE STEERING CONTROL

2.1 Introduction

2.1.1 Assisted Steering

Power steering systems have been used for years as a driver aid on production vehicles to make steering easier and safer. More recently, manufacturers have begun to increasingly intervene in the steering process to vary the sensitivity of the steering as a function of the speed of the vehicle. Though true steer-by-wire systems are not available in production automobiles for safety reasons, they are sometimes used in heavy construction or for parking assist systems such as the Toyota Intelligent Parking Assist System.

2.1.2 DC Motor Position Control

For this laboratory, you will use the QDS in conjunction with a Qube Rotary Servo to develop a PD position controller to regulate the steering angle of the simulated vehicle. The controller that you will design takes the steering angle command from the internal driving controller, and the actual steering angle from the Qube encoder signal. The PD controller then outputs the appropriate motor voltage, V_m, to actuate the Qube motor. A block diagram of the overall system is shown in Figure 2.2.

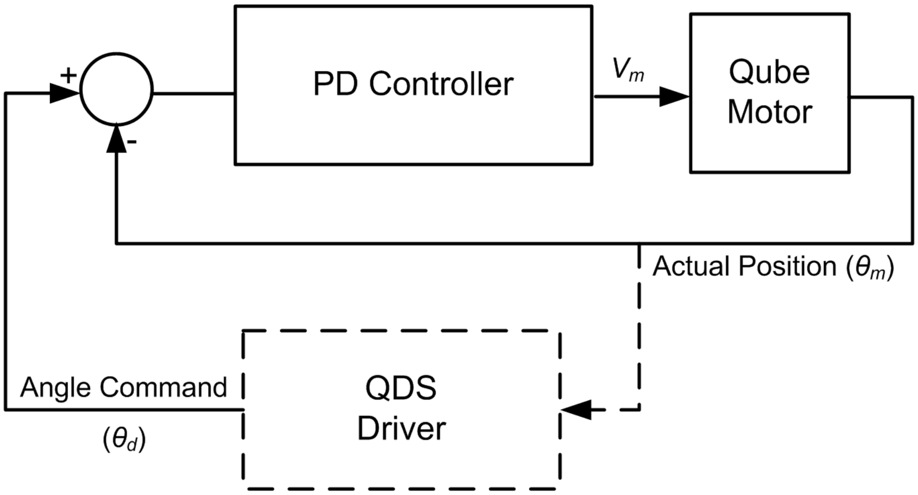

Figure 2.2: QDS steering angle controller

2.2 Background

2.2.1 PD Control

The PD controller is one of the most common control algorithms. For position control, it combines the error reduction of proportional control, with the overshoot elimination of derivative control. The proportional control term tracks the instantaneous error, while the derivative term predicts the response of the system based on the slope of the response. Though the derivative control term is able to reduce overshoot and improve the settling time, the system can be susceptible to steady-state error.

The linear behavior of a PD controller in the time-domain can be described by:

$$u(t) = k_p(r(t) - y(t)) + k_d \left(\frac{d}{dt} r(t) - \frac{d}{dt} y(t) \right) \tag{2.1}$$

where u(t) is the control signal, r(t) is the reference, and y(t) is the measured process output.

Question 2.1
From Equation 2.1, determine the PD controller transfer function in the Laplace domain.

Answer 2.1
If you let $e(t) = r(t) - y(t)$ then the controller transfer function can be stated as:

$$\frac{U(s)}{E(s)} = C(s) = k_p + k_d s = K_c(s + z) \tag{Ans.2.1}$$

where K_c is the controller gain and z is a zero.

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2.2.2 Root Locus

The root locus provides valuable insight into how the stability of a closed-loop system changes as the poles change with the system parameters (control gains). The root locus is constructed by plotting the "branches", or closed-loop poles and zeros of the system as the closed-loop feedback gain is varied from 0 to ∞ on the complex plane. The stability of the system depends on the relative positions of the poles of the system on the real axis. An example of the root locus for the Qube model is shown in Figure 2.3.

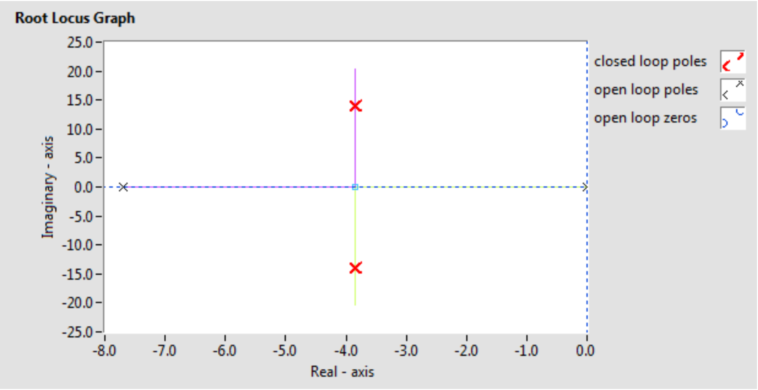

Figure 2.3: Root locus of the Qube motor model

2.3 Steering Controller Implementation

2.3.1 QDS Steering Control Implementation

1. Open the Quanser Driving Simulator model *Cruise Control.vi*.

   Note: If you are using the QUBE-Servo for NI myRIO, please begin by opening the *Steering Control - myRIO* LabVIEW project in the myRIO folder. The control subsystems are in the *QUBE-Servo Position Control - myRIO* VI deployed to the NI myRIO, and the simulation parameters in the *Steering Control* VI.

2. Open the *Steering Control* subsystem.

   Note: Ensure that the *Input Gain* block is set to 1 and the *DAQ* gain is set to ± 10 V

3. Navigate to the main block diagram.

   Note: Ensure that the *Steering Gain* block is set to -1.

4. Enter the k_p and k_d gains from the QUBE-Servo Position Control Lab into the *Kp* and *Kd* controls on the front panel.

5. Run the VI.

6. Observe the performance of the car as it makes a lap of the track.

Question 2.2
Is the controller able to track the desired steering angle effectively?

Answer 2.2
The controller may not track the desired steering angle well as shown in Figure 2.4 with the gains found in the QUBE-Servo Position Control Lab. The tracking error is due to a number of factors including: steady state errors inherent in the control architecture, differences between the step response used to tune the controller and the QDS steering inputs, the coupled effects of the automatic driver, and the differentiating filter. The gains can be increased to compensate. For example, a k_p gain of 4 and a k_d gain of 0.4 results in an improved response, shown in Figure 2.5.

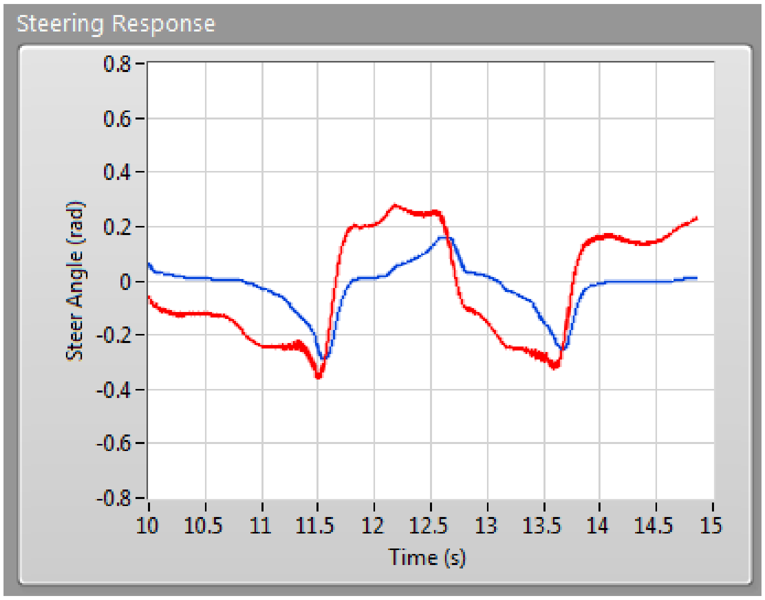

Figure 2.4: QDS steering controller results

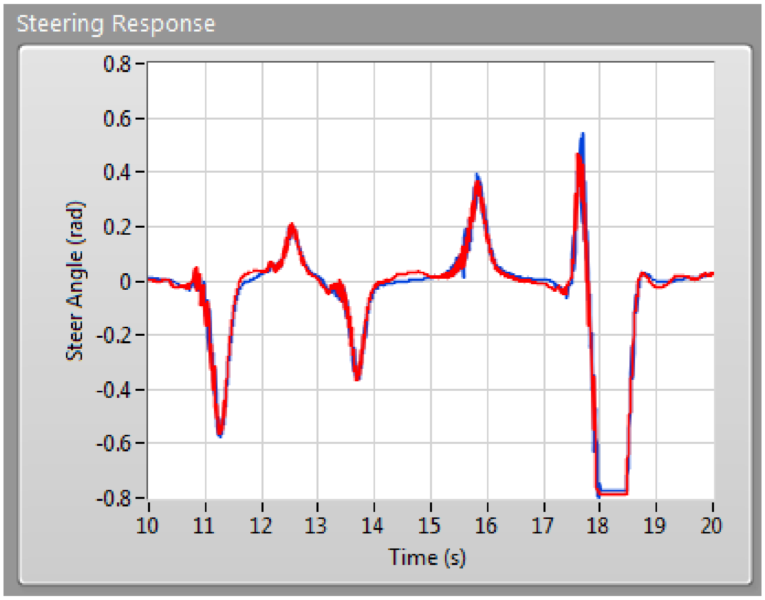

Figure 2.5: Tuned steering response

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Question 2.3
What changes could be made to the controller architecture to improve the performance of the steering controller?

Answer 2.3
The addition of an integral would compensate for steady-state errors in the control response. Altering the PD architecture to include a setpoint gain effectively creating a Proportional Velocity (PV) controller might also improve the performance of the system by decreasing spikes in the commanded voltage.

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7. If necessary, retune the controller gains to achieve the desired performance.

Question 2.4
Record the final control gains and response plots.

Question 2.5
How well did you perform compared to the steering controller? What can you say about real-world steering control systems?

Answer 2.4
The controller should be far better than a human driver in this scenario, which justifies the use of a position controller in this case (drive by wire, or remote control).

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Question 2.6
What other applications could a similar system have in the real world?

Answer 2.5
There are limitless creative solutions to this question. For example, the system could be used as a training device for learning how to drive a car, or to assist people with disabilities in driving. It could also be used as a rehabilitation system to guide post-stroke patients towards a given visual target.

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