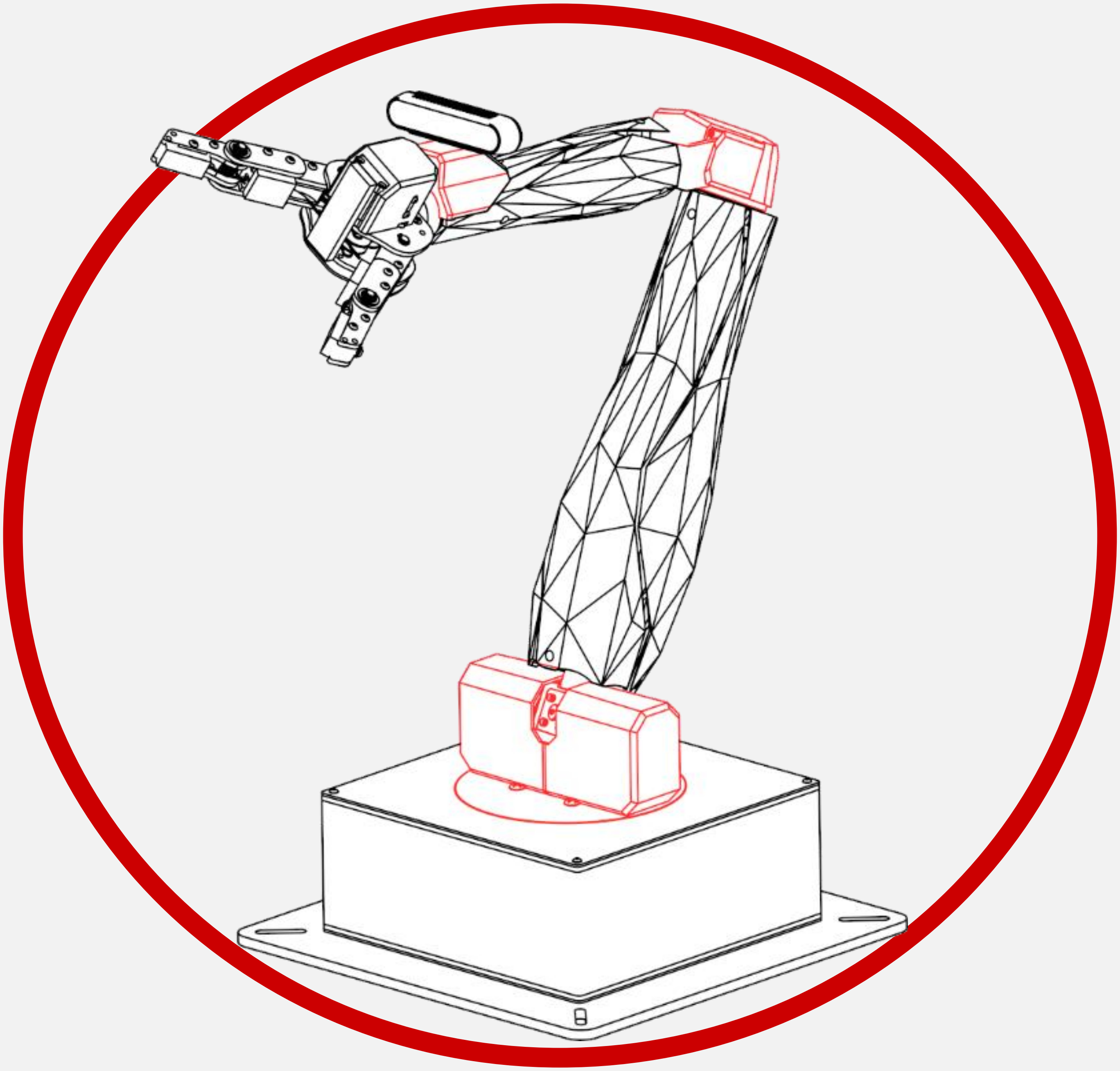

QArm

Low Level Control

V1.0 – 13th February 2025

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Caution

This equipment is designed to be used for educational and research purposes and is not intended for use by the public. The user is responsible for ensuring that the equipment will be used by technically qualified personnel only. Users are responsible for certifying any modifications or additions they make to the default configuration.

QArm – Application Guide

Low Level Control

Why explore Low Level Control?

As mentioned in the Basic I/O lab, most robotic arms are supplied with built-in controllers, however, the performance of those controllers may not meet the performance criteria for your specific application. Some manipulators prioritize accuracy, for example, one performing eye surgery. Other arms need to move quickly and prioritize speed, for example, a robot arm working on an assembly line. These tasks correspond to different performance criteria, which in turn require uniquely tuned controllers. This lab will explore how constituent components on a robotic arm can be designed to meet performance requirements. In doing so you will learn about concepts such as PID control, percentage overshoot, rise-time and more.

Background

The QArm content contains 5 labs that focus on kinematic manipulation. The first one focuses on learning how to do low level control, workspace identification, lead through control, teach pendant and trajectory generation. This lab focuses on how low level control is performed for a robotic manipulator.

Prior to starting this lab, please review the following concept reviews (should be located in Documents/Quanser/4_concept_reviews/),

- Concept Review – Intro to Control
- Concept Review – PID Control
- Concetp Review – Hardware Interfacing

Getting started

The goal of this lab is to study different methods for low level control for the QArm. A lab procedure will guide you on different methods for low level control and the unique effects present when trying to control a manipulator.

Before you begin this lab, ensure that the following criteria are met.

- The QArm has been setup and tested. See the QArm Quick Start Guide for details on this step.
- You are familiar with the basics of Simulink. See the Simulink Onramp for more help with getting started with Simulink.

Non-linear effects

One can expect that once the joint controllers are tuned to specification, the manipulator should behave consistently throughout its operation regime. However, in practice, the response of the manipulator changes depending on position and speed. These non-linear effects are the result of gravity and inertia.

Gravitational non-linear effects arise when gravity opposes or aids the motion of the arm. There are three scenarios that illustrate how these effects are manifested.

Scenario 1:

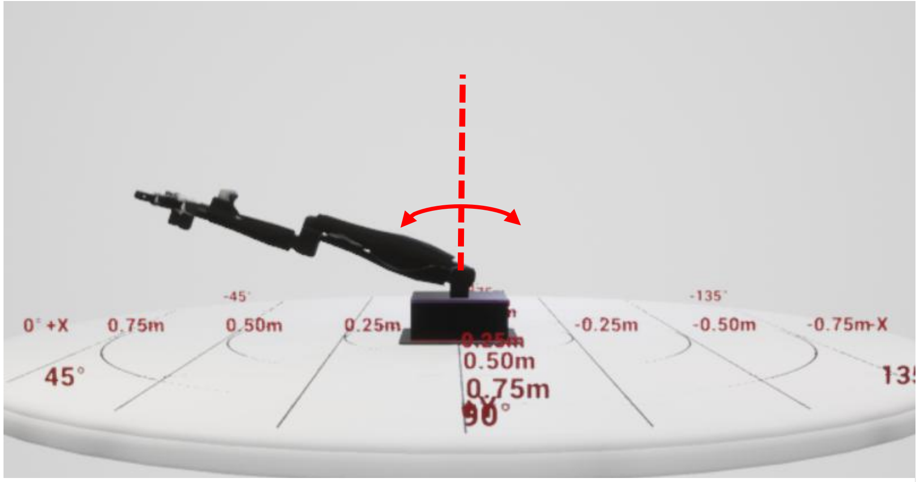

Figure 3 Scenario 1

In this scenario, the arm is outstretched vertically (elbow open to align lower and upper arms) and the shoulder oscillates symmetrically about a vertical setpoint (shown by the red dotted line). In this scenario, gravity acts equally in both directions.

Scenario 2:

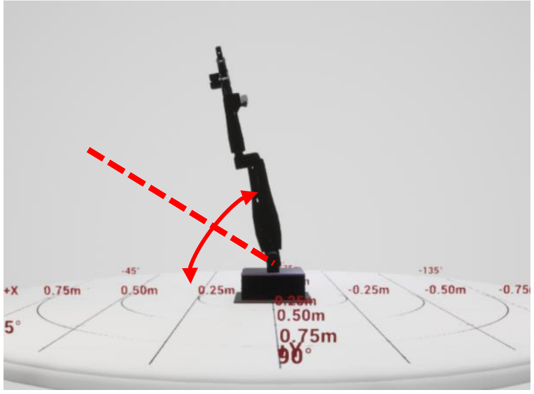

Figure 4 Scenario 2

In this scenario, the arm is still outstretched (open elbow) but the shoulder is not oscillating symmetrically around a vertical setpoint. The setpoint is offset to one side of the vertical, as shown by the red dotted line, and the shoulder oscillates about this position. Gravitational torques asymmetrically assist the shoulder when it moves the arm towards the table but slow the shoulder when it brings the arm back towards the vertical. To summarize, a joint's average position or motion setpoint affects its response due to non-linear factors.

Scenario 3:

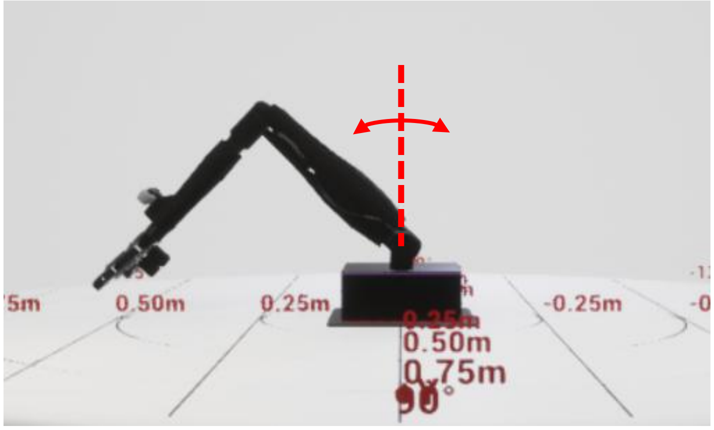

Figure 5 Scenario 3

In this final scenario, the arm is bent at the elbow and the shoulder is oscillating symmetrically around its setpoint. The centre of mass (CoM) of the bent arm is not aligned with the axis of the open arm. This also creates an asymmetrical gravitational boost/brake effect like scenario 2. To summarize, the average position or motion setpoint of other joints may also affect a joint into consideration.

You will witness the effects of gravity when the arm is placed in different orientations through the Lab Procedure. While the physical effect on the arm will be hard to spot, a Simulink scope can be used to measure overshoot and calculate PO. The effects of inertia on the arm are outside the scope of this lab and will be covered later.