QArm Lab Procedure
Lead Through

Setup

Caution: Please be extra careful in this lab as inappropriate steps may damage the arm and/or cause physical injury to the operators/students. Always maintain a safe distance away from the manipulator (greater than 1.5 m) unless specified not to explicitly.

1. It is recommended that you run this lab with a partner.
2. Prepare a flat surface stiff enough to stand vertically on the table with support as shown below. Note that this step is optional, but will help you visualize the trajectory better.

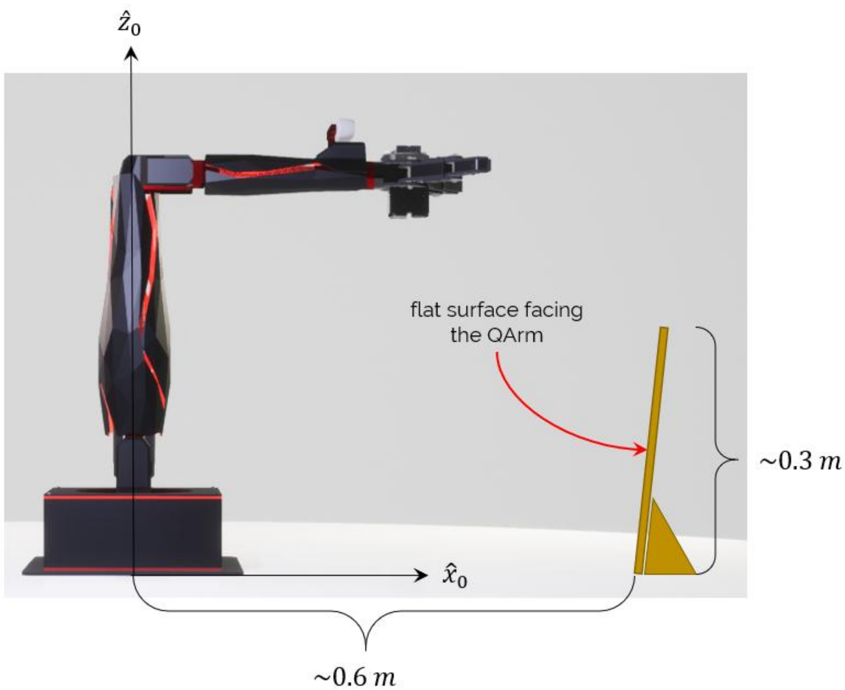

Figure 1: Suggested flat surface pose with respect to the manipulator

3. Move the QArm manipulator to the home position, and turn ON the unit using the power switch located on the rear side of the base. Once powered, the manipulator should hold this position.
4. Launch MATLAB and browse to the working directory for Lab 3 – Lead Through.

Lead Through (Learn)

1. Open LeadThrough_Learn.slx. This model uses a welding operation on a vertical plane to represent a lead through a learning process. Assign 2 students in your group members A and B. Student A will operate the arm and student B will control the Simulink model. You can swap after for each of you to try it.

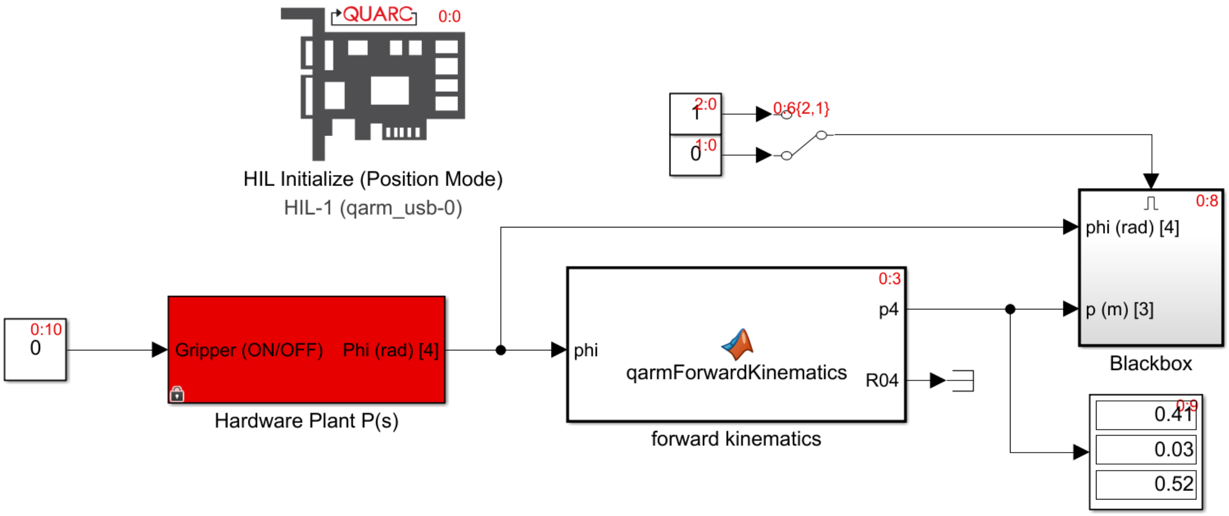

Figure 2: LeadThrough_Learn Simulink model.

2. Copy your finished ForwardKinematics function into this model.
3. Use a marker pen to draw a simple closed-loop trajectory on the cardboard. Keep a clearance of ~5 cm on the bottom end of the flat surface. An example is shown in Figure 3. Mark a single point as a starting/ending point.

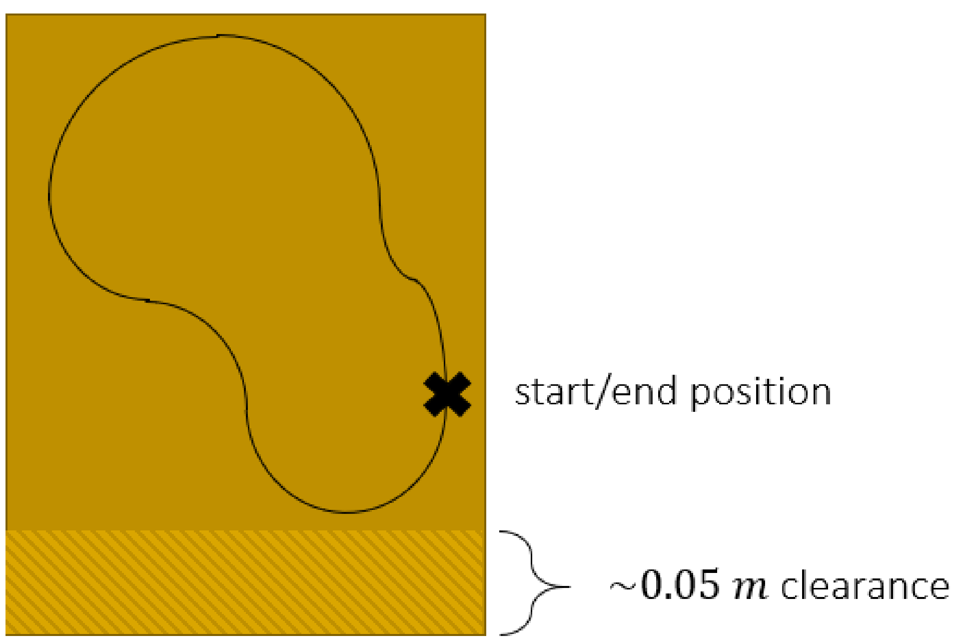

Figure 3: Example closed-loop trajectory on the flat surface with a 5cm clearance.

4. Student A - approach the arm and while supporting it, turn off the power using the switch at the rear end of the base. Move the arm to the rest position slowly. Now turn ON the power using the switch at the rear end. The manipulator should remain in the rest position. Place the flat surface as shown in Figure 1 in front of the manipulator.
5. Student B - prior to running the model, open the model's Configuration Parameters and verify that they are configured as follows:

    1. Solver type: Fixed-step

    2. Solver: ode4 (Runge-Kutta)

    3. Fixed-step size (fundamental sample time): 500 Hz

6. Student B - build and deploy the model using the Monitor & Tune action. When the model starts, the base LED will turn yellow and the arm will enter the PWM mode. No voltage command is written, allowing semi-free manipulation manually. Set the Gripper constant to 1 to close the gripper.

7. Student A - manipulate the manipulator by hand by gently guiding the end-effector to the starting position on your trajectory. Once here, and when ready, ask student B to enable recording using the manual switch.

8. Student A – guide the manipulator's end-effector and have it follow the custom trajectory. Note that the end-effector does not have to touch the flat surface. Use the flat surface trajectory as a guide. When you get back to the start/end point, ask student B to stop recording. This mimics one full cycle of a welding process along your custom trajectory.

9. Student B – once the recording is complete, stop the model. The arm should hold at the last position.

10. Student A - let go of the arm.

11. A window will pop up which plots the recorded trajectory. Make sure there is no discontinuity between the start and endpoint on the trajectory. Use to rotate the 3D plot.

12. Go to Matlab and under Command Window, you will see the distance between the starting and ending positions. If the deviation is more than 0.04 m, please record the trajectory again.

13. Close LeadThrough_Learn.slx.

Lead Through (Follow)

1. Open LeadThrough_Follow.slx. This model will take the trajectory data as inputs to recreate the welding process. Neither of the students needs to interact with the manipulator. Please maintain a distance of at least 1.5 m from the base of the manipulator at all times.

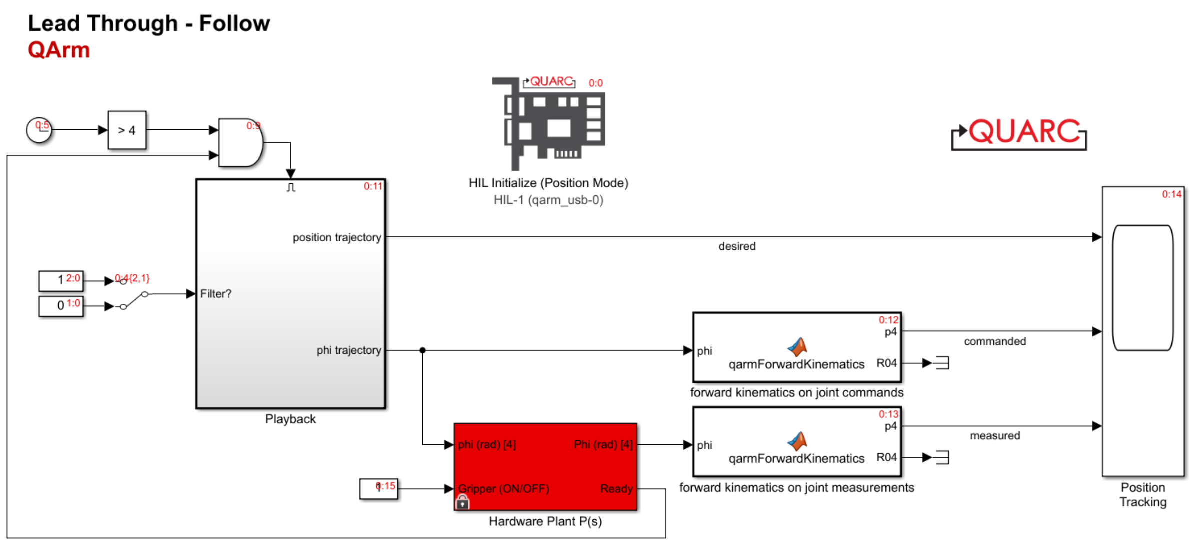

Figure 4 LeadThrough_Follow Simulink model

2. Copy your finished ForwardKinematics function into this model. Note that there are 2 instances of this method.

3. Prior to running the model, open the model's Configuration Parameters and verify that they are configured as follows:

    1. Solver type: Fixed-step

    2. Solver: ode4 (Runge-Kutta)

    3. Fixed-step size (fundamental sample time): 500 Hz

4. Ensure that the workspace is clear with only the flat surface standing in front of the arm. If the arm accidentally knocks down the surface, do not approach the working area to save it while the arm is operating.

5. With the **Filter?** input set to 0, build and deploy the model using the Monitor & Tune action. The arm will move from the position it was started in towards the start point of your recorded trajectory. Once there, it will start following the trajectory. When it reaches the endpoint, it jumps back to the start point and resumes in a cyclical format. Use the **Position Tracking** scope to comment on the repeatability performance metric and take a screenshot of a full welding cycle in the scope.

6. From the **Position Tracking** scope, take note of what has happened when the arm finishes one full loop. Is the arm jumpy at this point? Why or why not? The Position Tracking scope has 3 inputs, each being a cartesian position. The first input is the raw position trajectory recorded by the learning model. The second input is the raw joint angles trajectory recorded by the learn model and passed to the arm as a command. This is passed through the forward kinematics formulation for an appleto apple comparison. The third input to the scope is the measured joint angles trajectory, also passed through the forward kinematics formulation. As such, the three inputs represented the 'desired', 'commanded' and 'measured' position trajectories. Take a screenshot of a full cycle.

7. While the model is still running, flip the filter's manual switch to 1 to enable filtering. In this case, the commanded trajectory is filtered before being passed to the arm. Use the **Position Tracking** scope to compare the performance with the screenshot that you took before the filter is on. Take a screenshot of a full cycle.

8. Stop the model.

9. Approach the manipulator, support it and turn OFF the power using the switch at the rear end of the base. Move the arm to the rest position.

10. Close MATLAB.