Lab 3 Manual

Robotics & Automation
Dylan Losey, Virginia Tech

1 Introduction

Welcome to the third robotics lab! The GTAs are here to facilitate your learning and help with any technical challenges. Please be kind, professional, and respectful to the GTAs.

Objective. This lab has two objectives:

- Finding the robot's forward kinematics
- Identifying the robot's workspace

Figure 1: Geomagic Touch at your workstation.

2 Calibrating the Robot

Multiple groups use each workstation. Between sessions the robot needs to be re-calibrated. You must complete these steps at the start of *every* lab. On the plus side, you practiced these same steps during Lab 1 & 2.

Action 1

Perform the following checks:

- The computer licences are paired with specific Geomagic Touch robots. Confirm that your computer has the same number as your Geomagic Touch workstation.
- Make sure that the ethernet cable coming out of the Geomagic Touch is connected to the back of the computer, and the robot's charging cable is plugged in.

- Check that the computer is connected to the wifi "quanser_UVS" with password "UVS_wifi".

Hint. The computers are slow. Patience is a virtue. But if your connection to the robot is continually lagging throughout this lab, we recommend that you restart the computer.

Action 2

Now we are ready to initialize our robot arm. Open the Geomagic Touch Diagnostic Tool application shown in Figure 2. Then complete the following action items:

Figure 2: Application to check your connection to the Geomagic Touch.

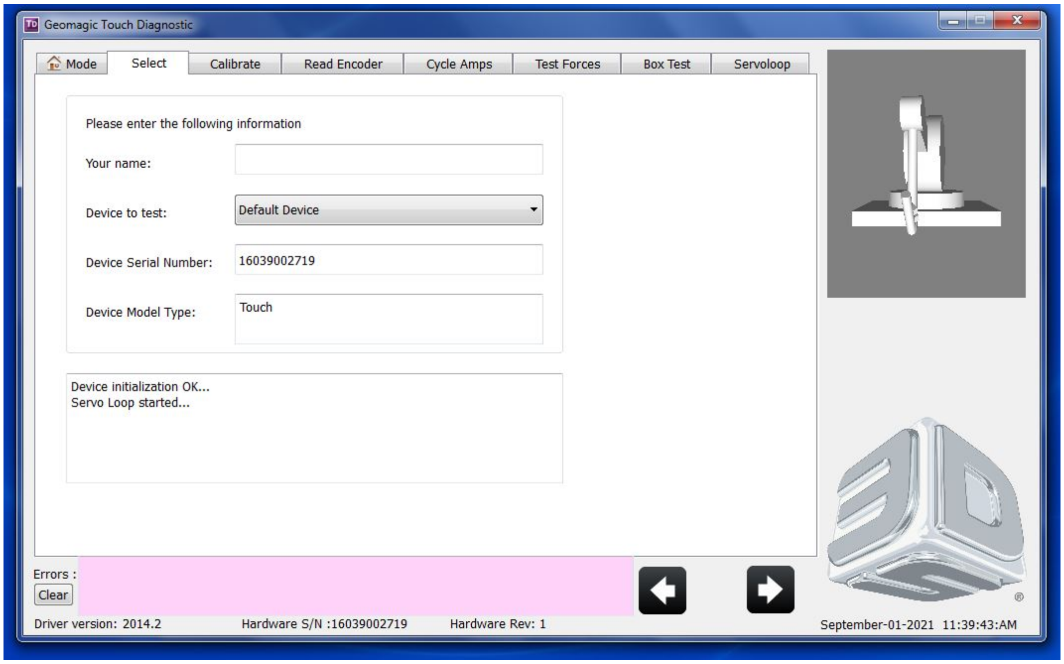

Figure 3: Geomagic Touch Diagnostic Tool. There is a 3D rendering of your robot arm in the top right. This should move in sync with your robot.

- When you open the application, you will see a tab at the top called **Select**. Click on this tab to see a small 3D model of your robot (shown in Figure 3). When you move the actual robot this 3D model should move as well. *If the 3D model is not moving when you move the robot ask a GTA for help.*

- Once you've ensured that the robot is connected, click on the **Calibrate** tab. Follow all the instructions on the screen to calibrate the robot (i.e., plug the pen into the holder for several seconds until the calibrate button turns green).
- Make sure to **close** the Diagnostic Tool after calibration. Otherwise it will conflict with Simulink in later steps.

Action 3

Let's open and run the initial Simulink model for this lab.

- In MATLAB, open the Forward Kinematics Simulink model: `..\Desktop\03 Forward_Kinematics\Forward_Kinematics_2015b_Start.mdl`
- You should see the Simulink diagram shown in Figure 4.

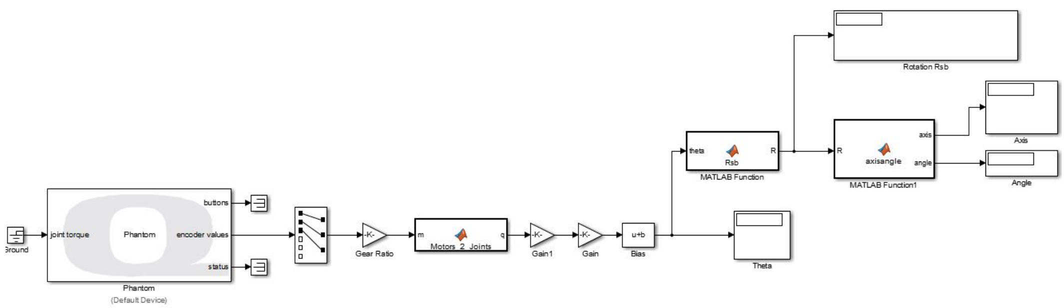

Figure 4: Initial Simulink diagram for the lab. Your team developed this during Lab 2.

- Build the simulation by going to the QUARC menu and clicking on **Build**. When the MATLAB Command Window shows that the model has been downloaded to the target, run the simulation by opening the QUARC menu and clicking on **Start**.
- Place the robot's end-effector on **position 2** of the baseboard. The positions on the **scope** for each revolute joint *in this lab* should read:

$$\theta_1 = 0.0 \quad \theta_2 = -0.3 \quad \theta_3 = 0.26 \tag{1}$$

  If your positions do not match, modify the **bias** block until the robot is correctly calibrated. Note: this won't be perfect, but try to get as close as possible.

3 Forward Kinematics

Question 1

Both L_1 and L_2 are 0.132 meters in length. Write the transformation matrix $M = T_{sb}(\theta = 0)$.

Question 2

Find the screws S_1, S_2, and S_3 for the three revolute joints.

Action 4

Implement a forward kinematics function in your Simulink model. This block should input the joint position θ and output two components of the transformation matrix T_{sb}:

- Rotation matrix R_{sb}
- Position vector p_{sb}

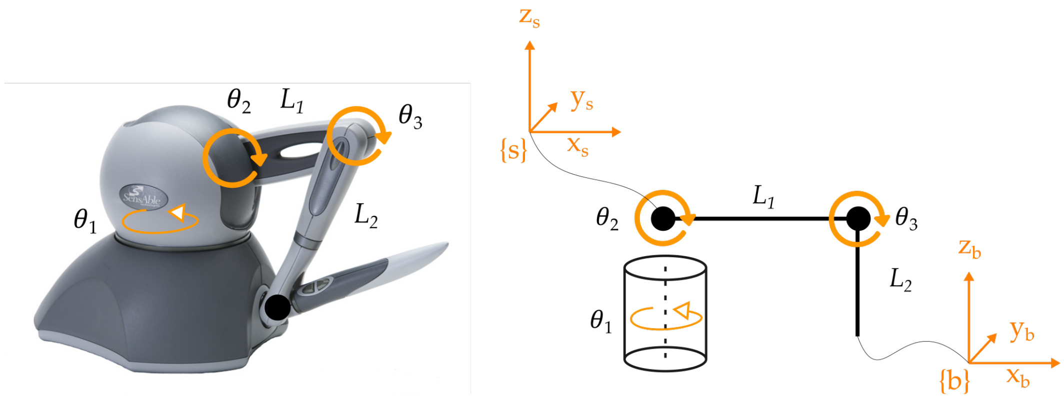

Figure 5: Joints of the Geomagic Touch. On right the robot is shown in its home position where $\theta_1 = \theta_2 = \theta_3 = 0$. Here $\{s\}$ is the fixed frame and $\{b\}$ is a coordinate frame at the end of link L_2. Notice that $\{s\}$ and $\{b\}$ align in this home position.

As a hint, the formula you need is $T_{sb} = e^{[S_1]\theta_1}e^{[S_2]\theta_2}e^{[S_3]\theta_3}M$. Include **scopes** or **displays** to render R_{sb} and p_{sb} in real-time.

Action 5

In Lab 2 you found the rotation matrix R_{sb} by using a sequence of body frame rotations. Confirm that your new forward kinematics function is outputting the same rotation matrix as your code from Lab 2. If not, you have a problem!

4 Transformation Matrices

Question 3

Referring back to Figure 5, notice that the x_s axis is pointing towards the front of the robot. But perhaps you have a different coordinate frame in mind: you want y_s to point towards the front of the robot, so that extending the arm increases the y position of T_{sb}. Write the new forward kinematics equation you would use to perform this transformation.

Note: *Do not implement this change.* You can of course test your solution as needed, but *revert back* to the $\{s\}$ coordinate frame from Figure 5 before proceeding.

Question 4

Move the end-effector to each of the marked positions on the board. Record p_{sb}. To sanity check your answers, the side of each grid cell is 0.05 meters.

Question 5

The GTAs will now check your forward kinematics. Hold the robot in joint position:

$$\theta_1 = 0.5 \quad \theta_2 = -0.7 \quad \theta_3 = -0.1 \tag{2}$$

Then ask the GTAs to come over and see T_{sb}. They will mark on your sheet whether you have a correct / incorrect R_{sb} and p_{sb}.

5 Workspace

When we control the robot it's useful to know where are robot can reach. For example, imagine that there is an object in front of the robot that we want to grab. Before we tell the robot to go to reach for that object, we should double check that this position is actually possible! In the final part of this lab, you will use the forward kinematics to experimentally measure the workspace of the robot.

Question 6

While running the Simulink model you built, carefully move the robot as far as you can (*without pressing or pulling the robot too hard*). What is the maximum x value you can reach? What about the minimum x value? Separately looking at x, y, and z axes, determine the minimum and maximum positions in meters.

Question 7

Imagine that you are given some arbitrary joint position θ. For that θ, how many possible values of T_{sb} could the robot have? Put another way, is $\theta \rightarrow T_{sb}$ a one-to-one mapping or a one-to-many mapping? Discuss your answer within your team.