Appendix A

Mathematica and Robotica

A.1 Mathematica Basics

- To execute a cell press <`Shift`>+<`Enter`> on the keyboard or <`Enter`> on the numberic keypad. Pressing the keyboard <`Enter`> will simply move you to a new line in the same cell. In addition you can select the "Evaluation–Evaluate Notebook" menu item and all your cells will be evaluated.

- Define a matrix using curly braces around each row, commas between each entry, commas between each row, and curly braces around the entire matrix. For example:

$$M = \{\{1, 7\}, \{13, 5\}\}$$

- To display a matrix use `MatrixForm` which organizes the elements in rows and columns. If you constructed matrix `M` as in the previous example, entering `MatrixForm[M]` would generate the following output:

$$\begin{pmatrix} 1 & 7 \\ 13 & 5 \end{pmatrix}$$

  If your matrix is too big to be shown on one screen, Mathematica and Robotica have commands that can help (see the final section of this document).

- *To multiply matrices do not use the asterisk.* Mathematica uses the decimal for matrix multiplication. For example, `T=A1.A2` multiplies matrices A1 and A2 together and stores them as matrix T.

- Notice that Mathematica commands use square brackets and are case-sensitive. Typically, the first letter of each word in a command is capitalized, as in `MatrixForm[M]`.

- Trigonometric functions in Mathematica operate in radians. It is helpful to know that π is represented by the constant `Pi` (Capital 'P', lowercase 'i'). You can convert easily from a value in degrees to a value in radians by using the command `Degree`. For example, writing `90 Degree` is the same as writing `Pi/2`.

A.2 Robotica

- Robotica was written here at the University of Illinois in 1993 by John Nethery and M.W.Spong. In 2016 Mohammad Sultan and Aaron T. Becker from the University of Houston completely refreshed and enhanced Robotica and have given it the version 4.0. The easiest way to use Robotica is just by example. The below steps are going to have you check out Robotica and run the given example. Then you simply need to modify the example with the DH parameters for the UR3. NOTE: Robotica displays a stick figure of the manipulator associated with your DH parameters. To make the stick figure look reasonable for the UR3 use units of decimeters instead of meters or millimeters.

- First open a CMD prompt in Windows and change directory to where you would like to store your Robotica files. At the CMD prompt type:
"git clone https://github.com/RoboticSwarmControl/robotica".
This will check out Robotica and an example notebook robotica_V4_example.nb.

- Start Mathematica and load robotica_V4_example.nb. Once loaded you will see that this example is using a robot configuration that has a prismatic joint and two revolute joints. If the stick figure robot picture is not displayed select the Evaluation–Evaluate Notebook menu item to run the notebook.

- Modify the "ex" matrix, which is a matrix of all the DH parameters, for the UR3. The matrix is made up of five rows. Row 1 is specifying if the movable joint is prismatic 'p' or revolute 'r'. Row 2 DH paramter 'a' (called 'r' here in Robotica V4.0). Row 3 DH parameter

'α'. Row 4 DH parameter 'd'. Row 5 DH parameter 'θ'. Note that the variables are called q1,q2,.... REMEMBER to use units of decimeters for the UR3.

- Change the dimensions of the A and T matrixes being printed to 6th order instead of 3rd order.
- Once you have the UR3 DH parameters entered run the menu command Evaluation–Evaluate Notebook and after a few seconds the UR3 stick figure should be displayed.
- Now you can use the given controls to move around the animation of the UR3. Note the equations for the T_6^0. Also note in the first picture of the robot the H matrix (T_6^0) is calculated for the thetas that were set by the given sliders.

A.3 What Must Be Submitted with Robotica Assignments

For homework and lab assignments requiring Robotica, you must submit each of the following:

1. figure of the robot clearly showing DH frames and appropriate DH parameters
2. table of DH parameters
3. matrices relevant to the assignment or application, simplified as much as possible and displayed in `MatrixForm`.

Do not submit the entire hardcopy of your Mathematica file. Rather, cut the relevant matrices from your print out and paste them onto your assignment.