MECH564 – Introduction to Robotics

Exam II – Take-home (work alone, limit communication)

Complete Analysis of ADEPT 1 Robot

Note – Present all of your analytical results in the most simplified forms.

Given the link frame attachment and the link parameter table (LPT) (see attached) for the Adept 1 Robot, complete the following analyses:

1.) Sketch and fully dimension the reachable workspace. See the joint limits in the attached link parameter table.
[10 points]

2.) Perform the forward position analysis by deriving explicit equations for x, y, z, and ϕ (tool roll angle measured from x_0 and x_4 about the z_0 axis) in terms of θ_1, θ_2, d_3, and θ_4. In these expressions, use the link parameter names (not numerical values) listed in the LPT. Please simplify your expressions. Compare your equation results with actual robot results using HERE A and HERE #A. Do this at two different RIGHTY points and two different LEFTY points (from opposite sides of the workspace ... positive and negative y). Try to explain sources for any discrepancies between actual and theoretical results. Also, create a formula or algorithm relating our ϕ to Adept's "roll."
[10 points]

3.) Perform the reverse position analysis by deriving explicit equations for θ_1, θ_2, d_3, and θ_4 in terms of x, y, z, and ϕ. Use the link parameter names (not numerical values) in these expressions. Test your equations at the same four points as in question 2.
[20 points]

4.) Determine the Jacobian matrix [J], in simplified form, where:
[20 points]

$$\begin{pmatrix} \dot{x} \\ \dot{y} \\ \dot{z} \\ \dot{\phi} \end{pmatrix} = [J] \begin{pmatrix} \dot{\theta}_1 \\ \dot{\theta}_2 \\ \dot{d}_3 \\ \dot{\theta}_4 \end{pmatrix}$$

5.) Determine the Inverse Jacobian matrix $[J]^{-1}$ where:
[20 points]

$$\begin{pmatrix} \dot{\theta}_1 \\ \dot{\theta}_2 \\ \dot{d}_3 \\ \dot{\theta}_4 \end{pmatrix} = [J]^{-1} \begin{pmatrix} \dot{x} \\ \dot{y} \\ \dot{z} \\ \dot{\phi} \end{pmatrix}$$

6.) Test your result for $[J]^{-1}$ (and all other results) by numerically integrating θ_1, θ_2, d_3, and θ_4 (e.g., $\theta_1^i = \theta_1^{i-1} + \dot{\theta}_1^{i-1} \Delta t$ where $\dot{\theta}_1^{i-1}$ is calculated from $\dot{\bar{\theta}} = [J]^{-1} \dot{\bar{x}}$) for

$$(x, y, z, \phi)^0 = (200 \text{ mm}, 200 \text{ mm}, 700 \text{ mm}, 0°)$$

and

$$(\dot{x}, \dot{y}, \dot{z}, \dot{\phi}) = \left(1\frac{mm}{s}, 1\frac{mm}{s}, 0.25\frac{mm}{s}, 0\frac{°}{s}\right) = \text{constant}$$

where t = 0 s to 300 s with Δt = 1s. Plot the joint values vs. time, and y vs. x and z vs. x (calculated from the joint values) for this numerically integrated trajectory. Also, report the joint values (in °, mm) at t = 0 s, 150 s, and 300 s. Assume the robot is in the RIGHTY configuration. You can use a spreadsheet, MathCAD, MATLAB, a custom program or anything else you want to perform the calculations. Whatever you use, make sure you provide evidence (e.g., printouts of formulas or programs) showing that you have performed the calculations properly.
[20 points]

Adept 1 Link Parameter Table

i	α_{i-1}	a_{i-1}	d_i	θ_i
1	0	0	d_1 (877 mm)	θ_1 (-150° to 150°)
2	0	a_1 (425 mm)	0	θ_2 (-147° to 147°)
3	180°	a_2 (375 mm)	d_3 (0 mm to 198 mm)	0
4	0	0	0	θ_4 (-277° to 277°)