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ME 5140
Intro to Robotics

6DOF Puzzle Solving Robot

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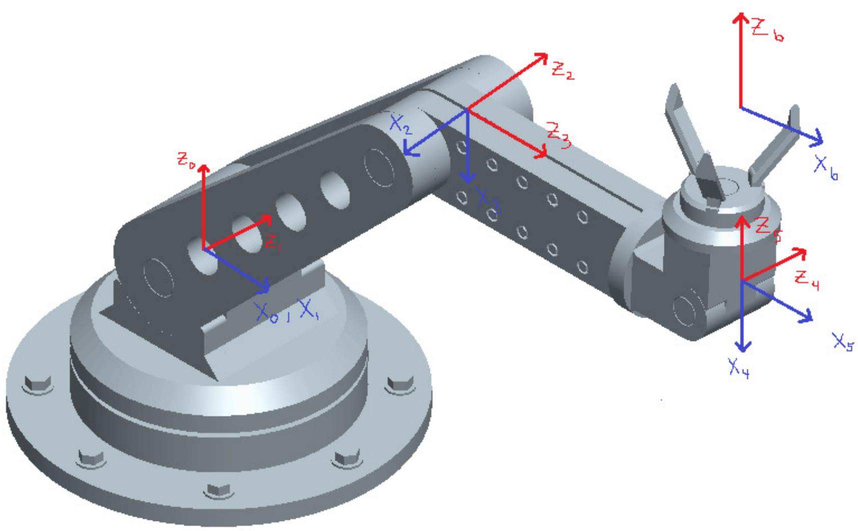
Summary

This robot is a 6DOF manipulator which consists of an articulated arm with a spherical wrist. It was designed using Pro/Engineer, and assembled and programmed in MATLAB. The current simulation allows for four modes of operation. The first is the ability to employ forward kinematics in the form of a "drive mode" in which the user is allowed to drive each joint of the robot individually. The second is an inverse kinematics capability which allows the user to enter any desired pose, or select a random pose. The inverse kinematics code finds all 8 solutions for the desired pose, but the current version of the program doesn't really utilize this capability. The inverse kinematics function of the simulation could easily be upgraded to path planning with via points. The third mode of operation is a demo mode in which the robot travels through a series of movements to demonstrate its capabilities. The fourth and final mode of operation is the puzzle solver mode. The program generates random 3space placement of four puzzle pieces, and the robot assembles them to a desired location and orientation. When completed, the puzzle spells "TTU ME".

Kinematics



Link i	a_i	α_i	d_i	Θ_i
1	0	-90	0	theta_1
2	-10	0	0	theta_2
3	0	90	0	theta_3
4	0	-90	9.25	theta_4
5	0	90	0	theta_5
6	0	0	5.25	theta_6

Once the D and H table has been formed, the forward kinematics transformations can easily be derived using the following matrix equation:

$$^{n-1}T_n = \left[\begin{array}{ccc|c} \cos\theta_n & -\sin\theta_n\cos\alpha_n & \sin\theta_n\sin\alpha_n & r_n\cos\theta_n \\ \sin\theta_n & \cos\theta_n\cos\alpha_n & -\cos\theta_n\sin\alpha_n & r_n\sin\theta_n \\ 0 & \sin\alpha_n & \cos\alpha_n & d_n \\ \hline 0 & 0 & 0 & 1 \end{array}\right] = \left[\begin{array}{ccc|c} & R & & T \\ \hline 0 & 0 & 0 & 1 \end{array}\right]$$

Inverse kinematics were derived using the kinematic decoupling technique which is possible because the robot satisfies Pieper's Theorem. This means that the three rotation axes of the wrist intersect at one point known as the wrist center. The location of the wrist center (x_c,y_c,z_c) was found using this equation:

$$\begin{bmatrix} x_c \\ y_c \\ z_c \end{bmatrix} = \begin{bmatrix} O_x - d_6 r_{13} \\ O_y - d_6 r_{23} \\ O_z - d_6 r_{33} \end{bmatrix}.$$

Where, O_x,O_y,O_z, is the last column of the transformation matrix of the wrist center, T_4^0. The orientation can be found by the equation:

$$R_6^3 = (R_3^0)^{-1} R = (R_3^0)^T R.$$

Using these methods, the inverse kinematics equations below were derived:

```
1. theta3 =  asin(a)
     a. a = ((x_prime^2+y_prime^2+z_prime^2-185.5625)/-185);
2. theta2 = acos(z_prime/e)-rho,
     a. rho = atan(-1.0811/c3+tan(theta3(elbow(i))));
     b. e = (9.25*c3)/cos(rho);

3. theta1 = atan2(t2,t1);
     a. t1 = x_prime/(9.25*s3*c2 + 9.25*c3*s2 - 10*c2);
     b. t2 = y_prime/(9.25*c3*s2 + 9.25*s3*c2 - 10*c2);
4. theta5 = [acos(R(3,3)),2*pi-acos(R(3,3))];
5. theta4 = atan2(b,c);
     a. b = R(2,3)/s5;
     b. c = R(1,3)/s5;
6. theta6 = atan2(R(3,2)/s5,-R(3,1)/s5);
```

Code will be submitted by email if requested.

Works Cited

Mathworks. <www.mathworks.com>.

Spong, Mark W., Seth Hutchinson and M. Vidyasagar. Robot Modeling and Control. John Wiley & Sons Inc, 2006.