ME 221, Fall 2022 HW 1
University of California, Riverside Due: 10/6/2022
Department of Mechanical Engineering

1. Find a commercial robot of your choice and answer the following:
   a. What is the robot model and manufacturer?
   b. How many links does the robot have?
   c. How many joints and what type?
   d. What is the total degrees of freedom?
   e. What type of actuators are used?
   f. What types of sensors are used?
   g. What types of controller interfaces are supported?
   h. What is a good application for your chosen robot?

2. Find the total degrees of freedom:
   a. Shoulder, elbow, forearm and wrist (arm)
   b. Hip, knee, and ankle (leg)
   c. Head
   d. Both hands fixed on a steering wheel

3. Consider the following rotation matrix:

$$\mathbf{R}(\phi) = \begin{bmatrix} \cos\phi & -\sin\phi & 0 \\ \sin\phi & \cos\phi & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

   a. Show that $\mathbf{R}$ is orthogonal.
   b. Show that the determinant is $+1$ for all ϕ.
   c. Are all matrices with $|R| = 1$ rotation matrices? Support your answer with an example.

4. Show that the product of two rotation matrices is also a rotation matrix.

5. Show that the unit vectors of a body frame $B(Oxyz)$, expressed in the global frame $G(OXYZ)$, are linearly independent.

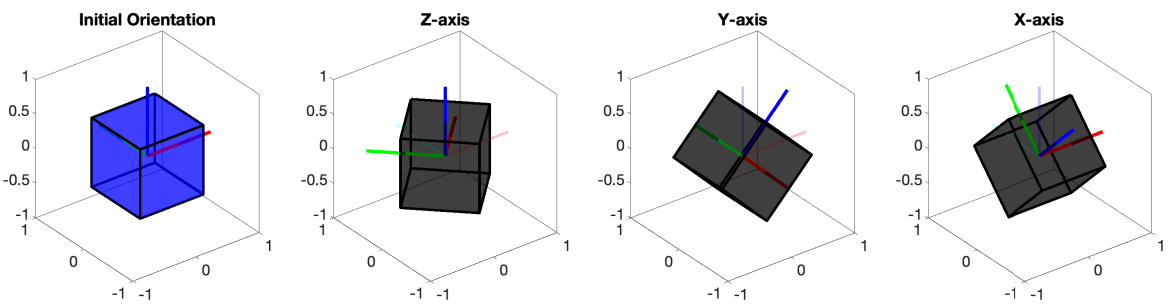

Figure 1: Solution plot for Problem 7(a).

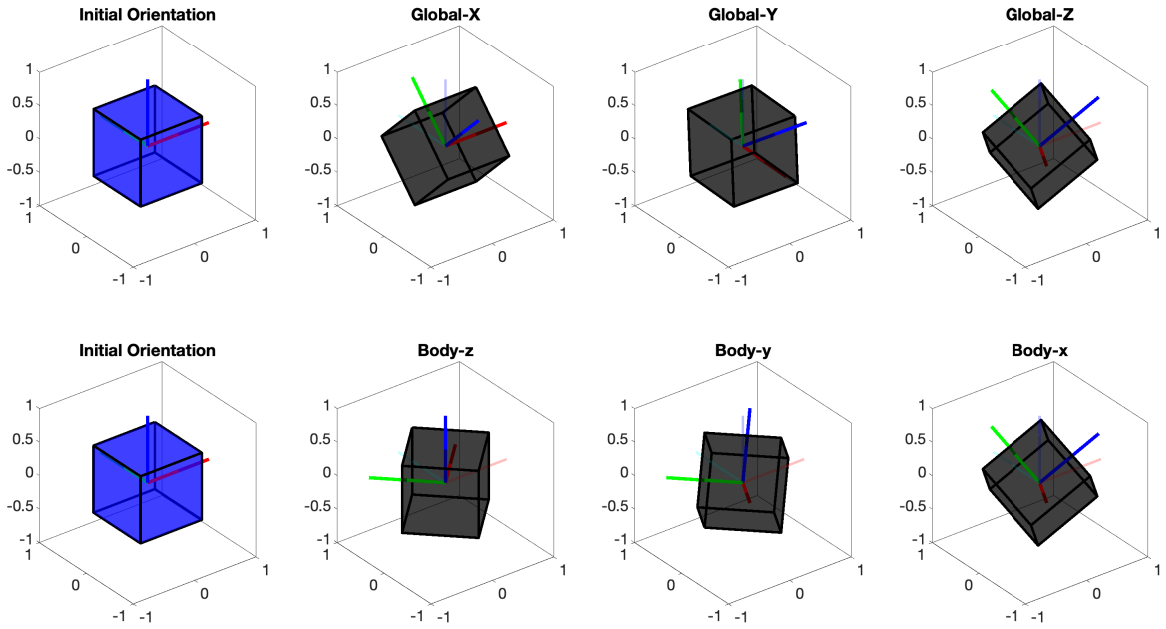

Figure 2: Solution plot for Problem 7(b).

6. Consider a rotation matrix $\mathbf{R}$ representing a rotation of 45° about the Z axis followed by a rotation of 90° about the new axis X. Find the equivalent axis/angle representation.

7. Download the MATLAB code `hw1_7.m`. The code can be used to generate and plot a cube. Become familiar with using the plotting functions. The code provides the initial matrix ${}^{B}\mathbf{S}_0$ which stores position vectors of the cube's vertices and it's attached Body coordinate frame—each *column* is a position vector. You should generate the proper rotation matrices to do the following (without using the built in MATLAB rotation functions):

   a. Generate a figure with subplots to show
      i. the original orientation
      ii. 45° rotation about Z axis
      iii. 45° rotation about Y axis
      iv. 45° rotation about X axis

      A sample figure is shown in Fig. 1.

   b. Show the equivalence of successive rotations in the Global and Body frames. First, using Global rotations, use successive 45° rotations in X-Y-Z. Starting with the initial configuration, show each successive rotation in it's own subplot. In a new row of subplots, do the same for the successive Body rotations z-y-x. The last subplot of each row should match. A sample figure in shown in Fig. 2.

   c. Create an animation of the cube with the following characteristics
      i. continuous rotation about the global Z-axis with constant angular velocity
      ii. constant rotation of 45° about the body y-axis
      iii. continuous rotation about the body z-axis with constant angular velocity but different magnitude than in part-i.

      To create the animation, initialize a video writer object:

```
VideoWriter('animation.mp4','MPEG-4');
open(v);
```

then use the plotting functions inside a `for` loop to generate each time instants and write each frame to the video writer object:

```
figure;                   % Initialize figure
for i=1:numOfFrames
  G_S_n = ...             % your rotation code goes here
  gcf; clf;               % get current figure, and clear
  plot_shape(G_S_n,...); % plot the shape
  plot_global_axis();     % plot axis
  frame = getframe(gcf); % get frame
  writeVideo(v,frame);    % write frame
  pause(0.01)             % forces plot to update
end
close(v);                 % close writer object
```

Be sure to submit both code and video to canvas. An example video is posted on the website.