

MATLAB Assignments

Spring 2024

MATLAB Assignment #1 Kinematics

due Thursday 3/28/2024, start of class

***NO LATE ASSIGNMENTS WILL BE ACCEPTED!***

MATLAB Assignment #1 focuses on the forward and inverse pose kinematics (FPK and IPK) of the human arm. The text is Section 4.2 of Dr. Bob's biomechanics NotesBook. Use the simplified planar 3-dof human arm model where  $L_1$  is the upper arm length,  $L_2$  is the forearm length,  $L_3$  is the hand length,  $\theta_1$  is the absolute shoulder pitch angle,  $\theta_2$  is the relative elbow pitch angle, and  $\theta_3$  is the relative wrist pitch angle.

For the adult male model ONLY, complete steps 1 (FPK) and 2 (IPK) below. For both cases, animate the simulated human arm to the screen (the FPK m-file in the Supplement shows you how to do this).

1. Perform **forward pose kinematics (FPK)** simulation in MATLAB according to the inputs below, for the adult male model. An example FPK MATLAB program is given for you in the 4670/5670 NotesBook – feel free to adapt this for your m-file.

**Inputs**

Use the joint limits from the NotesBook, repeated here for your convenience.

Angle	Min	Max
$\theta_1$	$-140^\circ$	$90^\circ$
$\theta_2$	$0^\circ$	$145^\circ$
$\theta_3$	$-70^\circ$	$90^\circ$

Then use a cosine function simultaneously for each angle:

$$\theta_i(t) = \theta_{iMID} + A \cos \varphi \quad \varphi = 0 \rightarrow 2\pi \quad i = 1, 2, 3$$

where  $\theta_{iMID}$  is the midpoint for each angle range, and  $A$  is the amplitude (half of each angle range). Artificially map the entire motion to a time range from 0 to 4 sec.

Plot:

- Input angles ( $\theta_1, \theta_2, \theta_3$ ) vs. time
- FPK results ( $x_H, y_H, \phi$ ) vs. time
- FPK results ( $y_H$  vs.  $x_H$ ; square axes with equal  $X, Y$  ranges)
- Simulated muscle lengths (biceps and triceps) vs. time
- Simulated muscle angles (biceps and triceps) vs. time
- Initial and final arm poses (square axes with equal  $X, Y$  ranges)

## MATLAB Assignment #1 Kinematics (cont.)

2. Perform **inverse pose kinematics (IPK)** simulation in MATLAB according to the inputs below, for the adult male model. The MATLAB program is **not** given for you in the 4670/5670 Supplement, but you can modify your FPK m-file.

### Inputs

The required initial pose is:

$$X_0 = [x_H \quad y_H \quad \phi] = [0.09 \quad -0.40 \quad 0]$$

Starting from the initial Cartesian pose  $X_0$  given above, add the following Cartesian offsets at each time step.

$$\Delta x_H = 0.001$$

$$\Delta y_H = 0.005 \text{ m}$$

$$\Delta \phi = -0.5^\circ$$

Use exactly  $N$  steps, where  $N+1$  steps causes an IPK singularity. What is  $N$ ? Artificially map the entire motion to a time range from 0 to 2 sec.

Plot:

- Input Cartesian pose ( $x_H, y_H, \phi$ ) vs. time
- IPK results ( $\theta_1, \theta_2, \theta_3$ ) vs. time
- Simulated muscle lengths (biceps and triceps) vs. time
- Simulated muscle angles (biceps and triceps) vs. time
- Initial and final arm poses (square axes with equal  $X, Y$ , ranges).

Are any human joint limits violated during this simulated motion?

The first page of your MATLAB Assignment #1 report must be a one-page memo. You are expected to work with others on the concepts and MATLAB strategies – **however, all computer programs and written work must be strictly individual**. Start early and ask me questions at any time; feel free to check your results with mine.

## MATLAB Assignment #2 Pseudostatics

due Thursday 4/11/2024, start of class

***NO LATE ASSIGNMENTS WILL BE ACCEPTED!***

MATLAB Assignment #2 focuses on the pseudostatics simulation of the human elbow joint driven by the biceps and triceps muscles. The text is Section 5.2 of Dr. Bob's biomechanics NotesBook. Use the further simplified planar 1-dof human arm model where  $L_1$  is the upper arm length,  $L_2$  is the forearm length,  $L_3$  is the hand length,  $\theta_1 = 0$  (constant) is the absolute shoulder pitch angle,  $\theta_2$  is the relative elbow pitch angle, and  $\theta_3 = 0$  (constant) is the relative wrist pitch angle.

For the adult male model ONLY, complete the assignment given below. For this pseudostatics simulation, animate the simulated human arm to the screen.

### **Inputs**

For super-smoothness, use the full cycloidal function for the elbow angle:

$$\theta_2(t) = \theta_{20} + (\theta_{2F} - \theta_{20}) \left[ \frac{t}{t_F} - \frac{1}{2\pi} \sin \frac{2\pi t}{t_F} \right]$$

with the following limits:

$$5^\circ \leq \theta_2(t) \leq 150^\circ$$

Artificially map the entire motion to a time range from 0 to 10 sec. Include a constant end load (vertical, down), i.e.  $W_L = 4.45$  N is given at the fingertip.

Perform **acceptable biceps/triceps pseudostatics** simulation in MATLAB, using a minimum tension of 150 N (in turn for the triceps and biceps muscles, respectively). Plot:

- Initial and final arm poses (square axes with equal  $X, Y$ , ranges).
- Cycloidal input angle  $\theta_2$  vs. time
- Biceps and triceps muscle lengths vs. time
- Biceps and triceps muscle angles vs. time
- Biceps/triceps pseudostatics results ( $t_B$  and  $t_T$  vs. time)
- Biceps/triceps pseudostatics results ( $F_{Ex}$  and  $F_{Ey}$  vs. time)

Discuss your results.

The first page of your MATLAB Assignment #2 report must be a one-page memo. You are expected to work with others on the concepts and MATLAB strategies – **however, all computer work and written work must be strictly individual**. Start early and ask questions at any time; feel free to check your results with mine.

## MATLAB Assignment #3 Dynamics

due Thursday 4/25/2024, start of class

***NO LATE ASSIGNMENTS WILL BE ACCEPTED!***

MATLAB Assignment #3 focuses on the dynamics simulation of the human elbow joint driven by the biceps and triceps muscles. The text is Section 6.2 of Dr. Bob's biomechanics NotesBook. Again, use the further simplified planar 1-dof human arm model where  $L_1$  is the upper arm length,  $L_2$  is the forearm length,  $L_3$  is the hand length,  $\theta_1 = 0$  (constant) is the absolute shoulder pitch angle,  $\theta_2$  is the relative elbow pitch angle, and  $\theta_3 = 0$  (constant) is the relative wrist pitch angle.

For the adult male model ONLY, complete the assignment given below. For this dynamics simulation, animate the simulated human arm to the screen.

### Inputs

Use the full cycloidal function for the elbow angle:

$$\theta_2(t) = \theta_{20} + (\theta_{2F} - \theta_{20}) \left[ \frac{t}{t_F} - \frac{1}{2\pi} \sin \frac{2\pi t}{t_F} \right]$$

with the following limits:

$$5^\circ \leq \theta_2(t) \leq 150^\circ$$

The time range is from 0 to 0.4 sec. Now you must calculate the associated rotational and translational velocities and accelerations.  $W_L = 4.45$  N is given at the fingertip.

Perform **acceptable biceps/triceps dynamics** simulation in MATLAB, using a minimum tension of 150 N (in turn for the triceps and biceps muscles, respectively). Plot:

- Initial and final arm poses (square axes with equal  $X$ ,  $Y$ , ranges).
- Cycloidal input angle  $\theta_2$  and all derivatives through jerk vs. time
- CG accelerations vs. time
- Biceps and triceps muscle lengths vs. time
- Biceps and triceps muscle angles vs. time
- Biceps/triceps dynamics results ( $t_B$  and  $t_T$  vs. time)
- Biceps/triceps dynamics results ( $F_{Ex}$  and  $F_{Ey}$  vs. time)

Discuss your results. Using your programs, identify explicitly how fast the final time must be before dynamics makes a significant different in the analysis, compared to pseudostatics only.

The first page of your MATLAB Assignment #3 report must be a one-page memo. You are expected to work with others on the concepts and MATLAB strategies – **however, all computer work and written work must be strictly individual**. Start early and ask questions at any time; feel free to check your results with mine.