



# ME 327: Design and Control of Haptic Systems

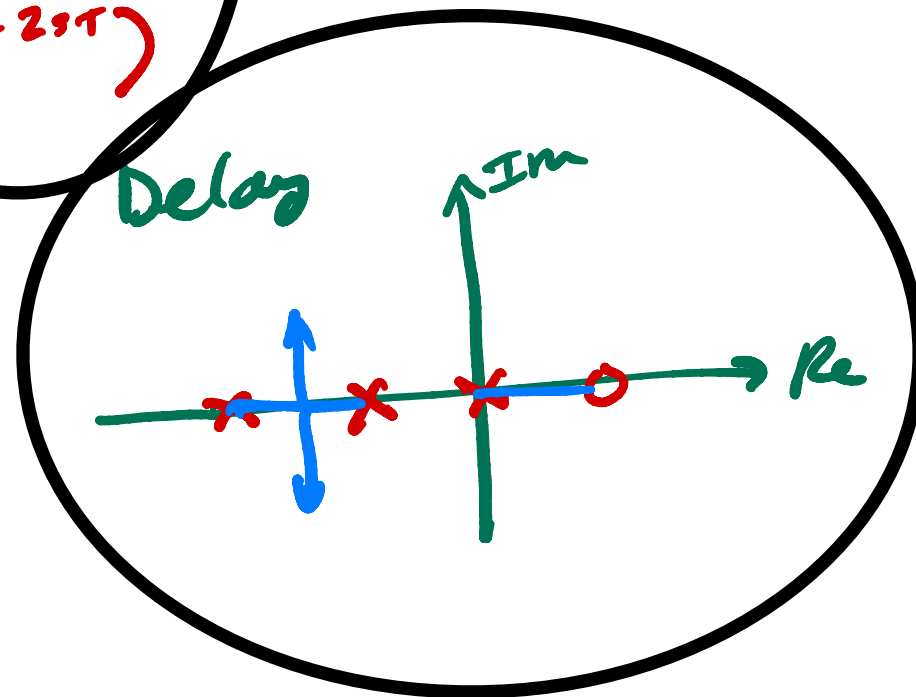
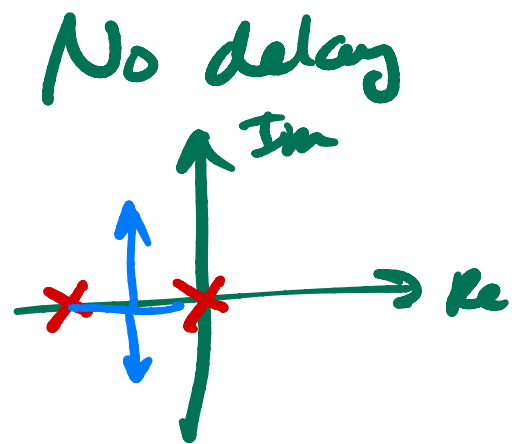
Spring 2020

## Interactive Session II: Kinesthetic haptic devices: multi-DOF design and kinematics

Allison M. Okamura  
Stanford University

# Correction from last Thursday

$$1 + \frac{K}{ms^2 + bs} \cdot \underbrace{\frac{1 - Ts}{1 + Ts}}_{(e^{-2sT})} = 0$$



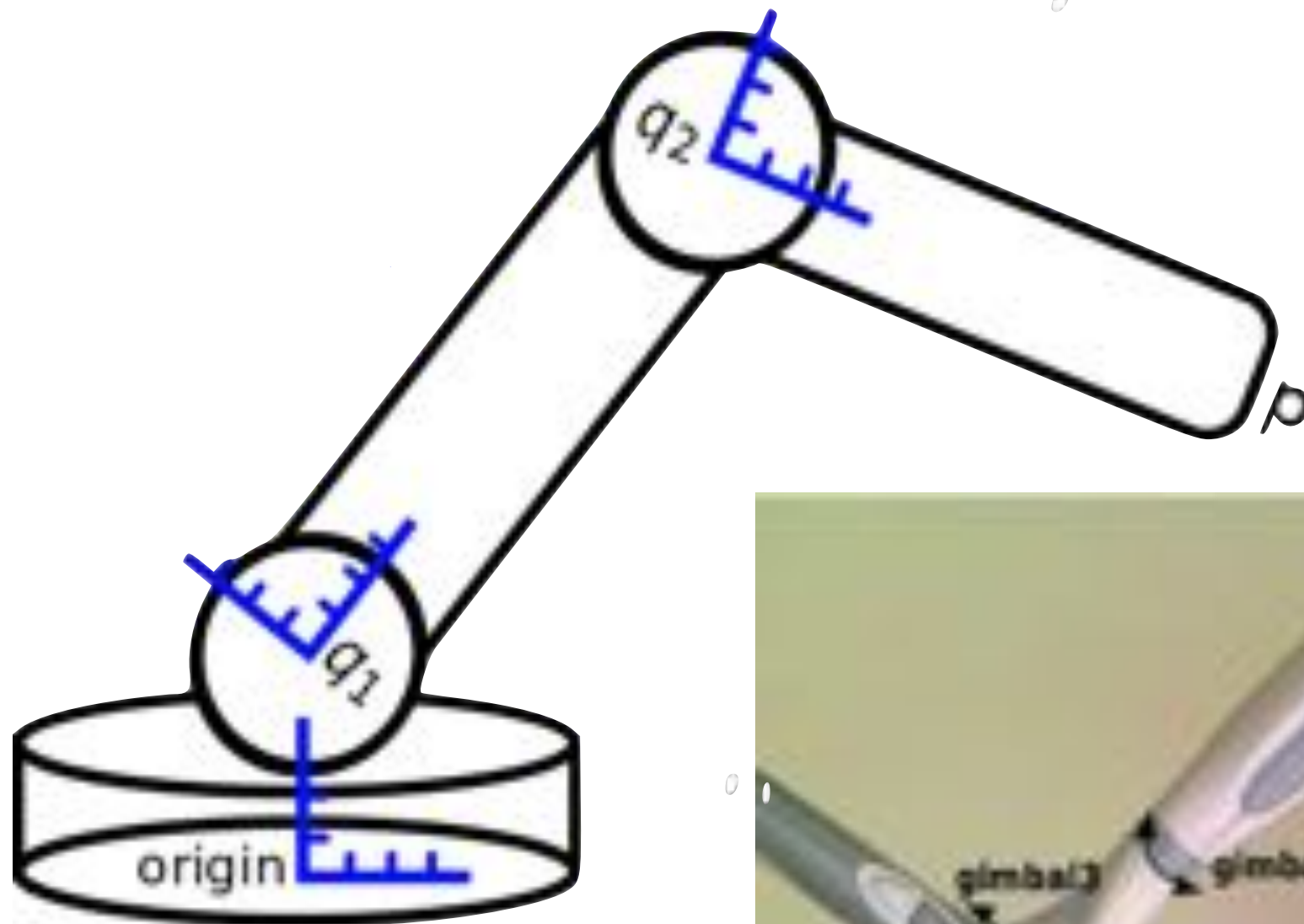
Questions from  
prerecorded video?

# Phantom Omni Design

# Phantom Omni



# Phantom Omni



Slide courtesy Tania Morimoto

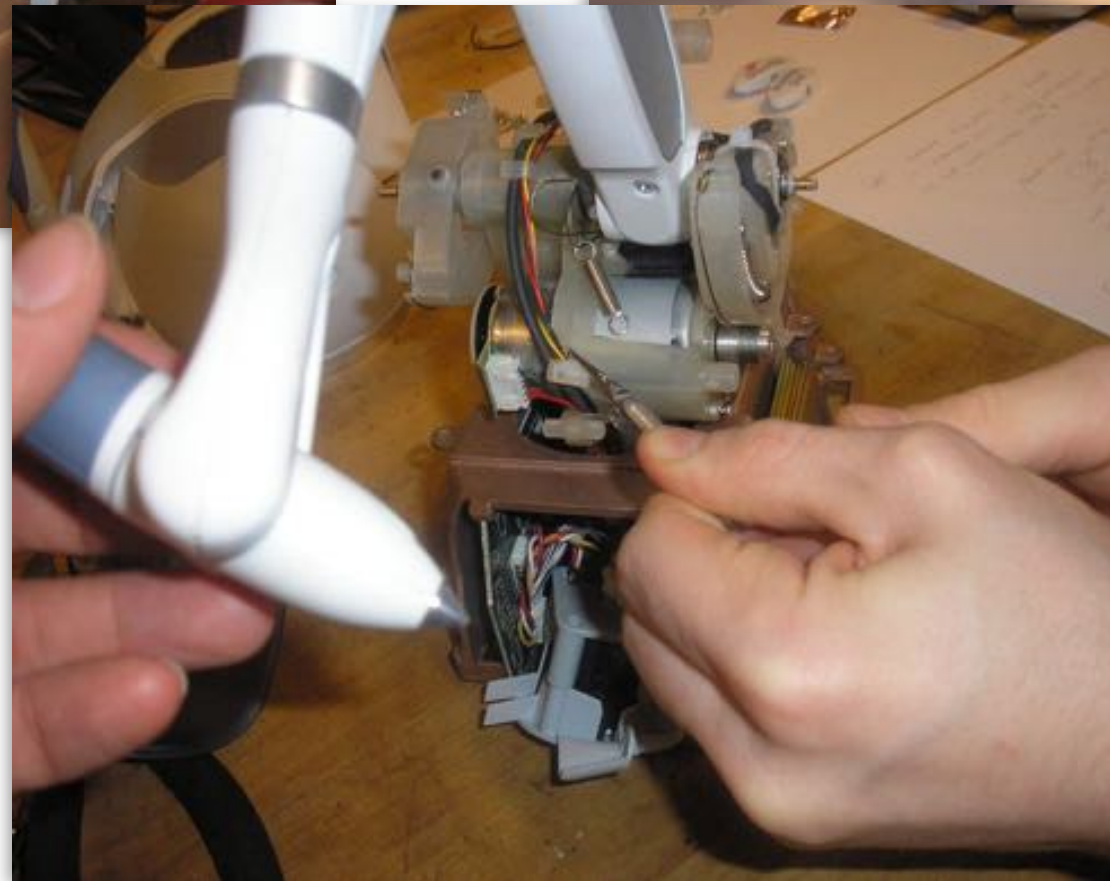
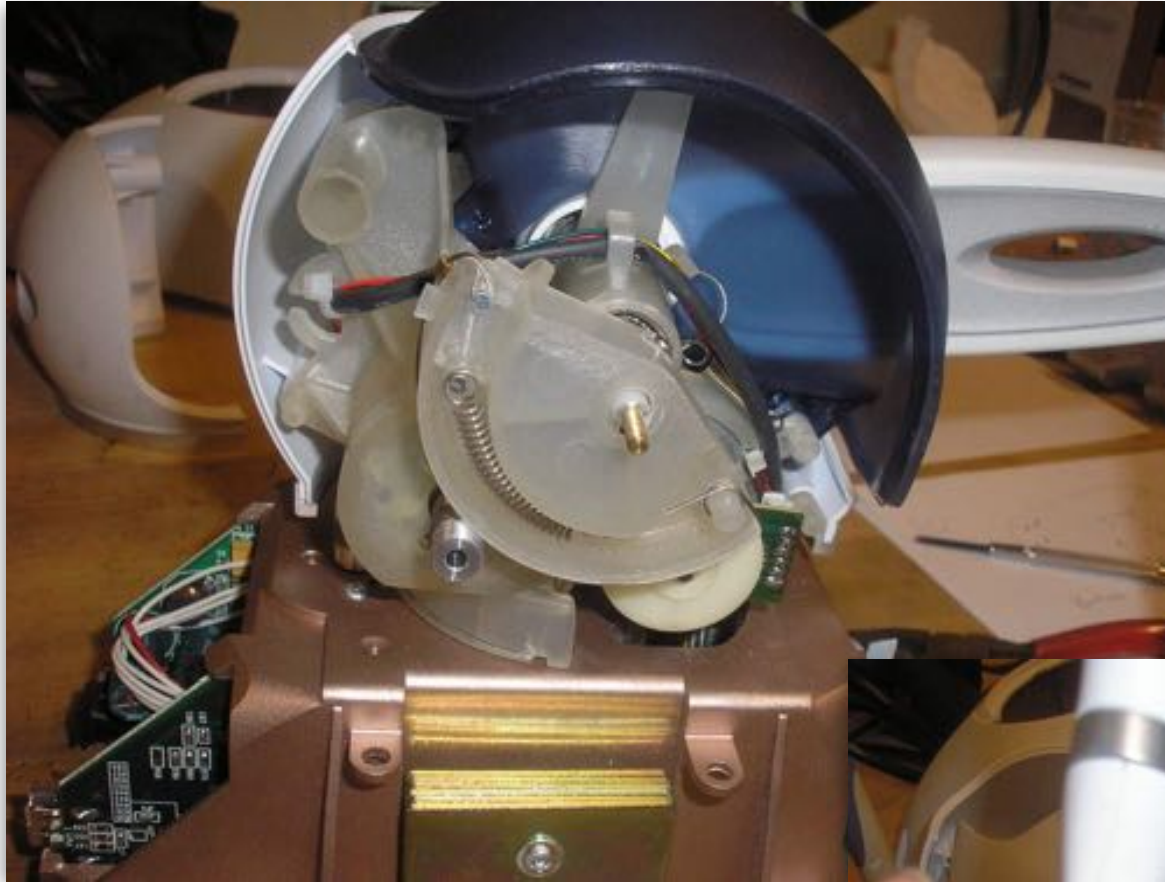
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# What is inside a Phantom Omni?

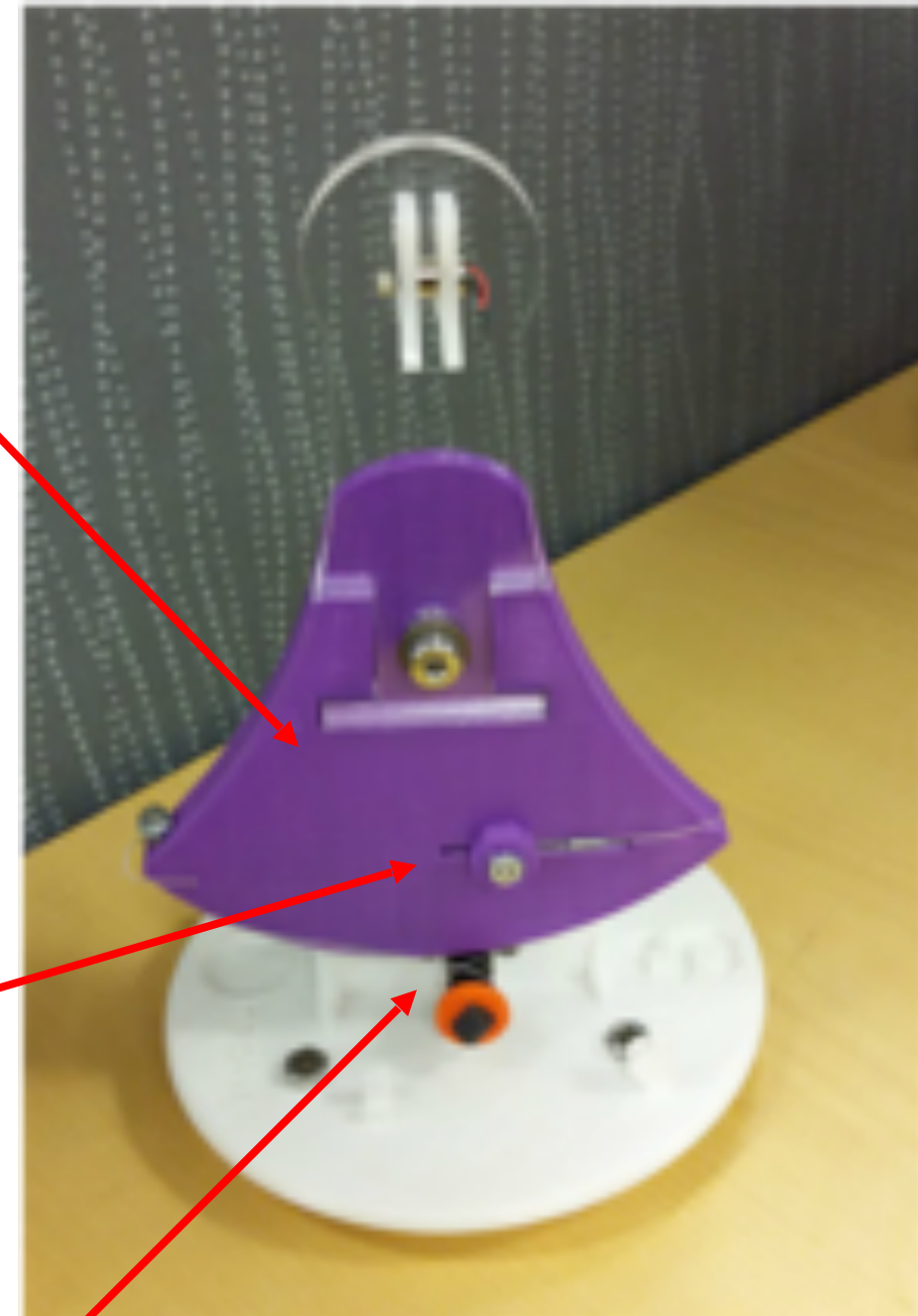
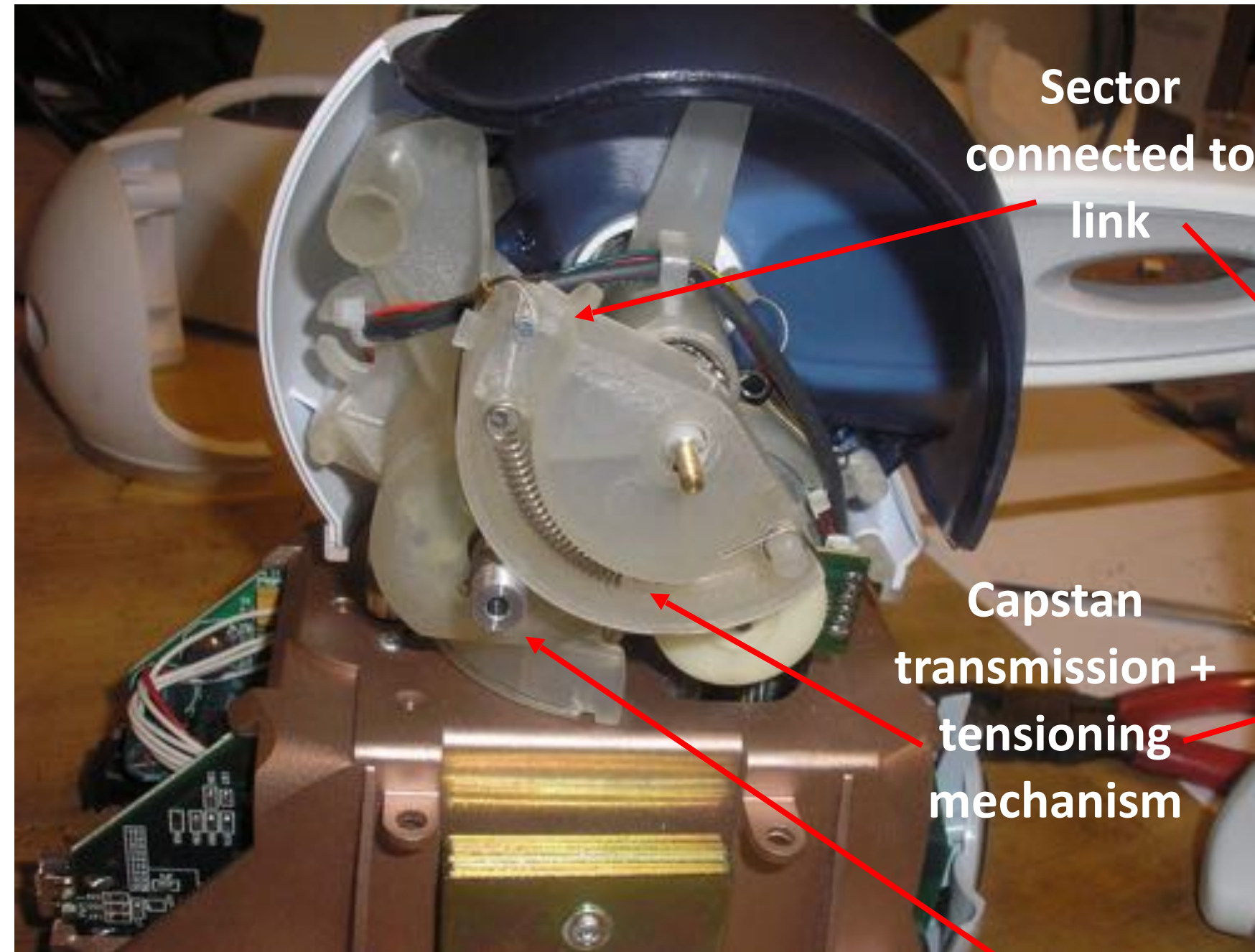


Slide courtesy Tania Morimoto

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# Omni vs. Hapkit



Sector  
connected to  
link

Capstan  
transmission +  
tensioning  
mechanism

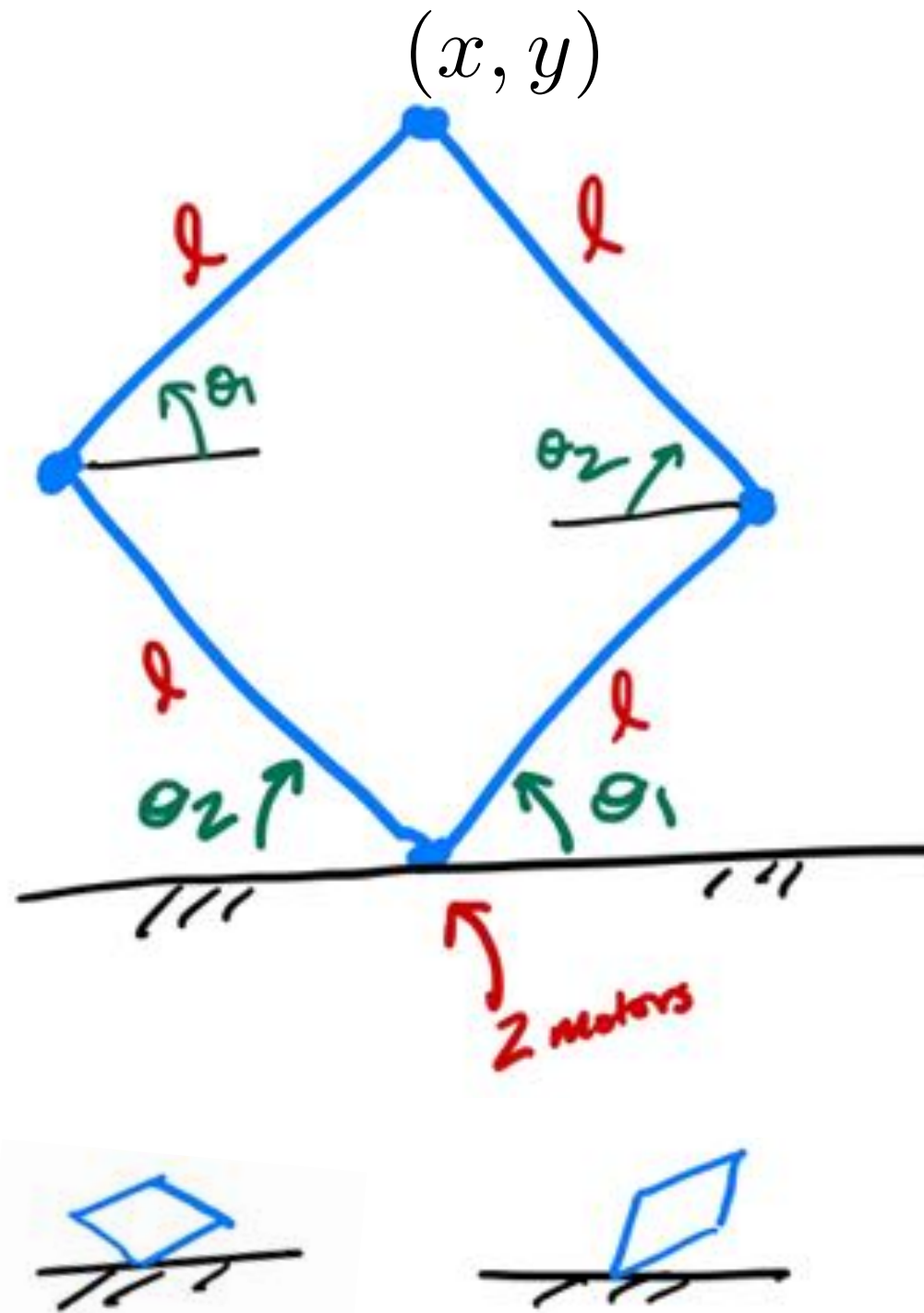
Motor

Slide courtesy Tania Morimoto

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# Pantograph Kinematics



In breakout groups:

1. Find the forward kinematics

$$x = f(\theta_1, \theta_2)$$

$$y = f(\theta_1, \theta_2)$$

2. Find the Jacobian

$$\begin{bmatrix} \dot{x} \\ \dot{y} \end{bmatrix} = J \begin{bmatrix} \dot{\theta}_1 \\ \dot{\theta}_2 \end{bmatrix}$$

3. Find the singularities

$$\theta_1, \theta_2?$$

① Forward kinematics

$$x = l_1 - l_2 \cos \theta_2$$
$$y = l_1 \sin \theta_2 + l_2$$

② Jacobian

$$\frac{dx}{d\theta_1} = -l_2 \sin \theta_2$$
$$\frac{dy}{d\theta_1} = l_2 \cos \theta_2$$
$$\frac{dx}{d\theta_2} = l_1 \sin \theta_2$$
$$\frac{dy}{d\theta_2} = l_1 \cos \theta_2$$
$$\begin{bmatrix} \dot{x} \\ \dot{y} \end{bmatrix} = \begin{bmatrix} -l_2 \sin \theta_2 & l_1 \sin \theta_2 \\ l_2 \cos \theta_2 & l_1 \cos \theta_2 \end{bmatrix} \begin{bmatrix} \dot{\theta}_1 \\ \dot{\theta}_2 \end{bmatrix}$$

③ Singularities

$$-l_2 \sin \theta_2 \cdot l_1 \cos \theta_2 - l_1 \cos \theta_2 \cdot l_2 \sin \theta_2 = 0$$

$$-s_2 c_2 = c_2 s_2$$

$$s_1/c_1 = -s_2/c_2$$

$$\tan \theta_1 = -\tan \theta_2$$

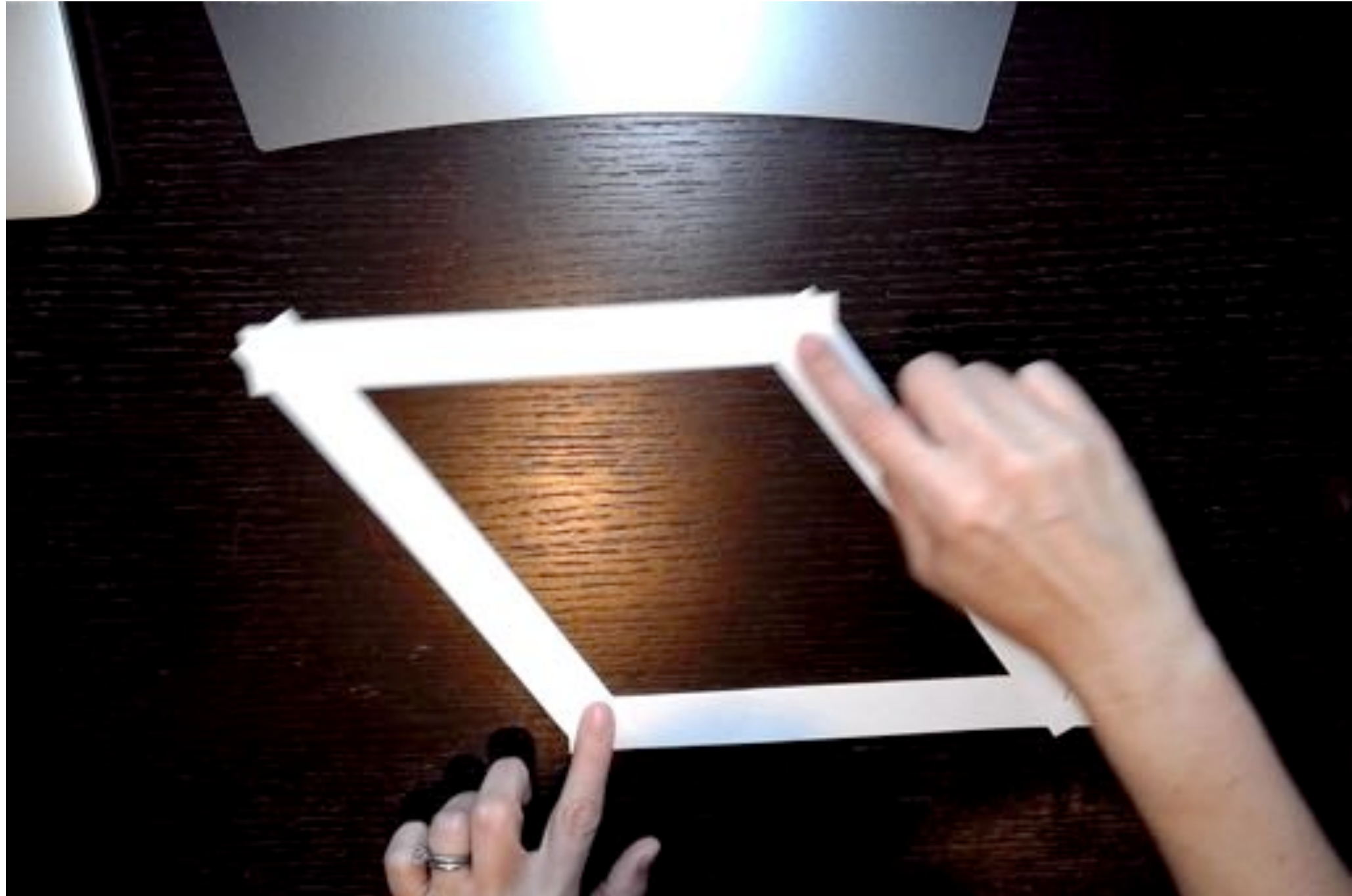
$$\theta_1 = -\theta_2 + n\pi$$

Examples:

$$\theta_1 = \theta_2 = 0^\circ$$

$$\theta_1 = \theta_2 = 90^\circ$$

# Pantograph Demo



# Reminders:

Assignment 5 due Thursday

Hapkits are on their way!

Quiz 2: 60 minutes, next Friday (Friday May 22)

Office Hours/Q&A with Allison until 10 am.

Question queue (see tab with today's date):

<https://tinyurl.com/HapticsAllison>