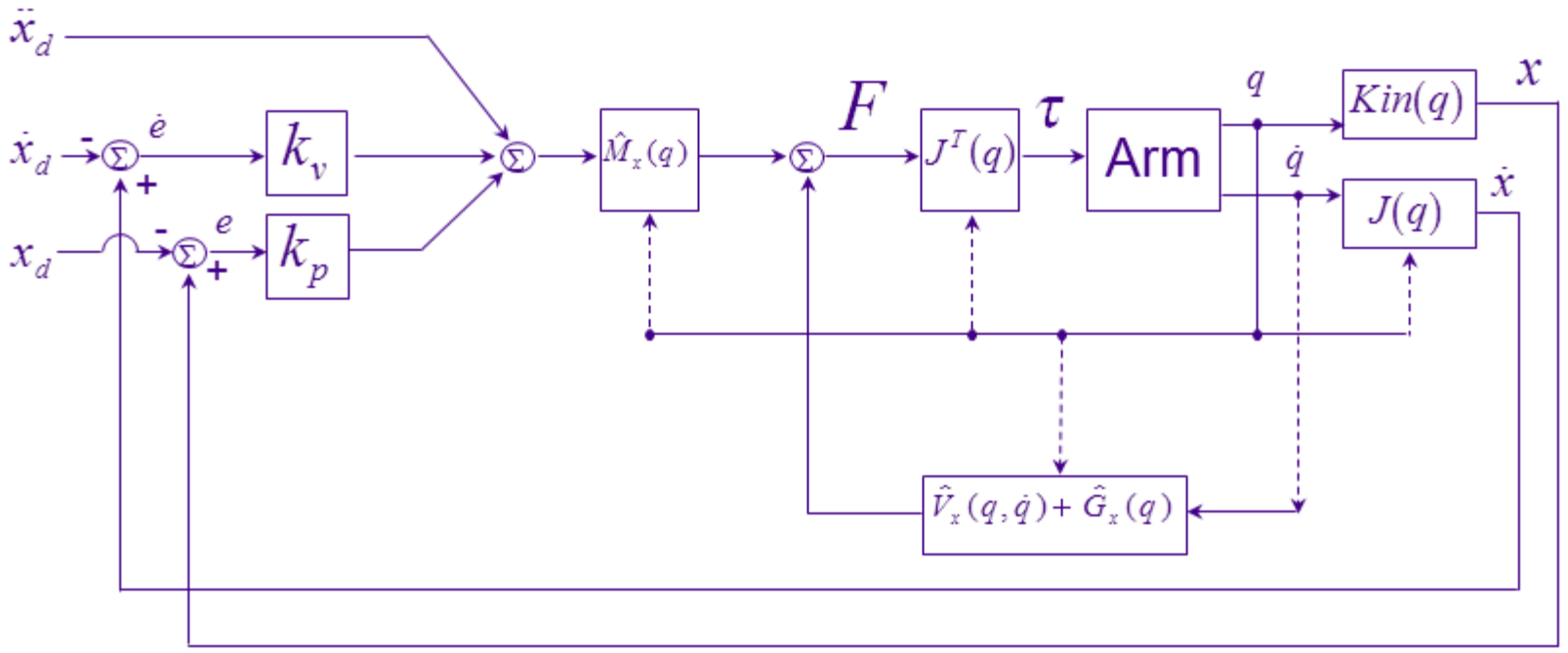
Video Segment

Reach and grasp by people with tetraplegia using a neurally controlled robotic arm, Leigh R. Hochberg *et al.*, nature, 2012

Task-Oriented Control

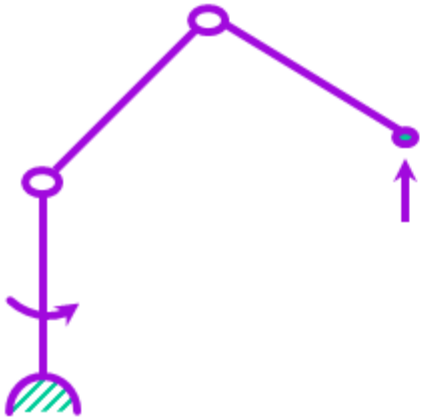


Compliance

$$I\ \ddot{x} = F'$$

$$F' = -\begin{pmatrix} k'_{p_x} & 0 & 0 \\ 0 & k'_{p_y} & 0 \\ 0 & 0 & k'_{p_z} \end{pmatrix} (x - x_d) - k'_v \dot{x}$$

set to zero



$$\ddot{x} + k'_v \dot{x} + k'_{px}(x - x_d) = 0$$

$$\ddot{y} + k'_v \dot{y} + k'_{py}(y - y_d) = 0$$

$$\ddot{z} + k'_v \dot{z} = 0$$

Compliance along Z

Stiffness

$$\ddot{z} + k'_v \dot{z} + k'_{p_z} (z - z_d) = 0$$

determines stiffness along z

Closed-Loop Stiffness: $\hat{M}_x k'_p = k_p$

$$F = K_x (x - x_d)$$

$$\tau = J^T F = J^T K_x \Delta x = (J^T K_x J) \Delta\theta = K_\theta \Delta\theta$$

$$\boxed{K_\theta = J^T(\theta) K_x J(\theta)}$$

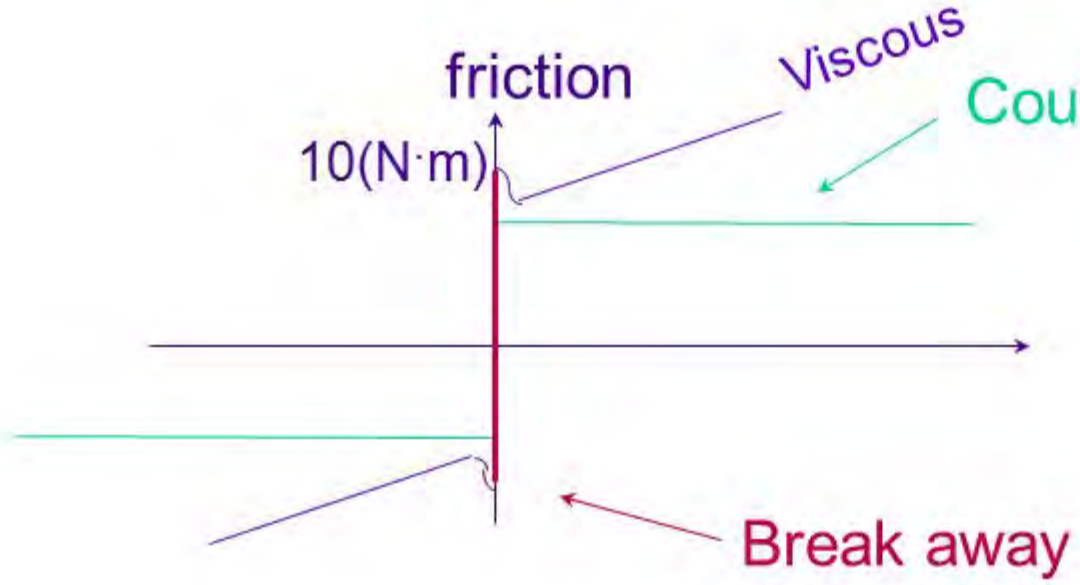
Force Control

1-d.o.f.

$$m\ddot{x} = f$$

set $f = f_d$

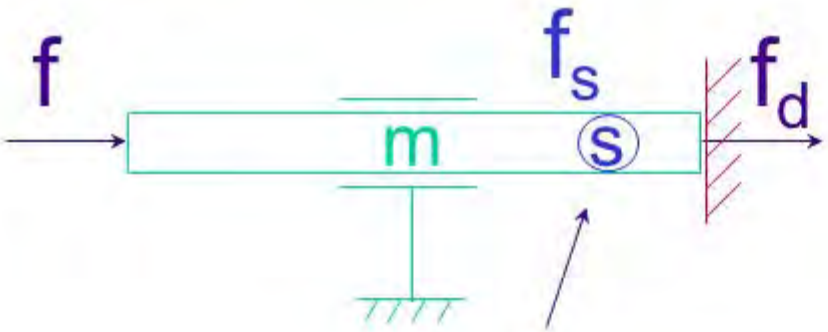
Problem



$f_d = 1Nm$

output≃0

Force Sensing



$$\text{s} \equiv \text{—}\sim\text{—} \quad ; f_s = k_s x$$

$$m\ddot{x} + \underbrace{k_s x}_{f_s} = f$$

At static Equilibrium

$$f_s = f_d \Rightarrow f = f_d$$

Dynamics

$$m\ddot{x} + k_s x = f_d + f_{Dynamic}$$

Dynamics

$$m\ddot{x} + k_s x = f$$

$$f_s = k_s x$$

$$\dot{f}_s = k_s \dot{x}$$

$$\ddot{f}_s = k_s \ddot{x}$$

$$\downarrow f_s$$

$$\frac{m}{k_s}\ddot{f}_s + f_s = f$$

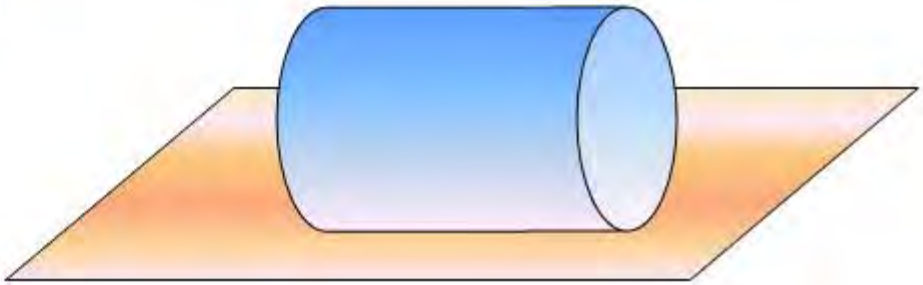
Control

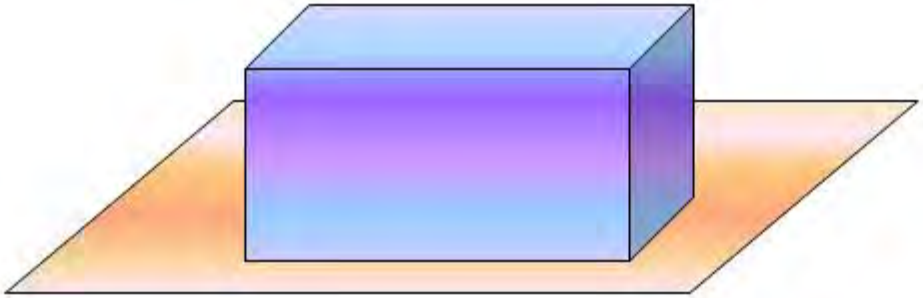
$$f_d + \frac{m}{k_s}(-k'_{p_f}(f_s - f_d) - k'_{v_f}\dot{f}_s)$$

Closed Loop

$$\frac{m}{k_s}[\ddot{f}_s + k'_{v_f}\dot{f}_s + k'_{p_f}(f_s - f_d)] + f_s = f_d$$

Task Description

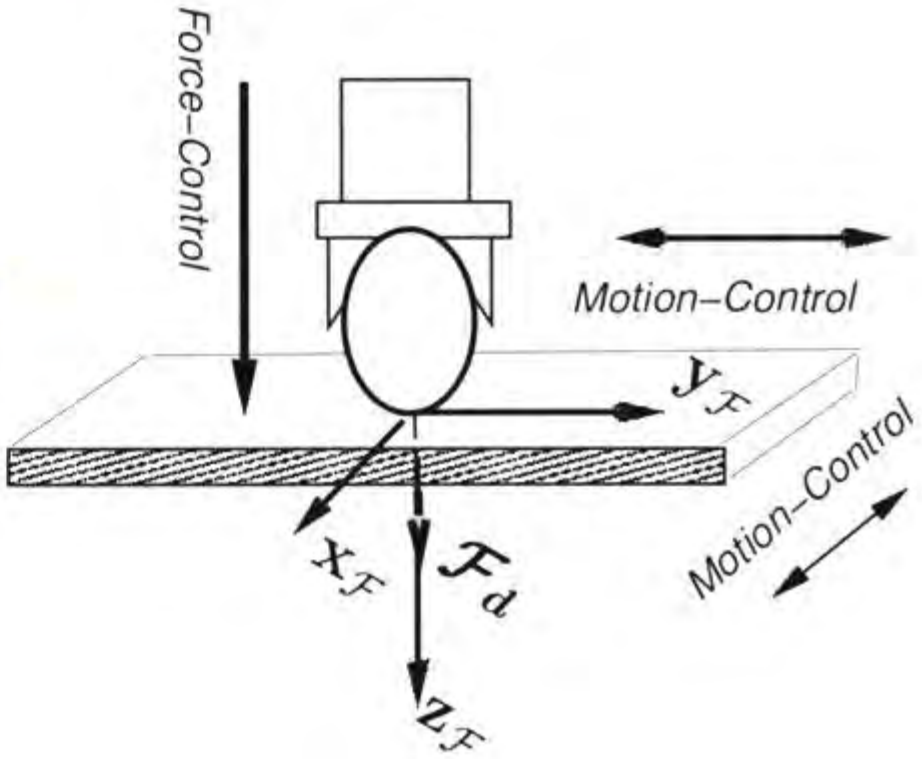




Task Specification

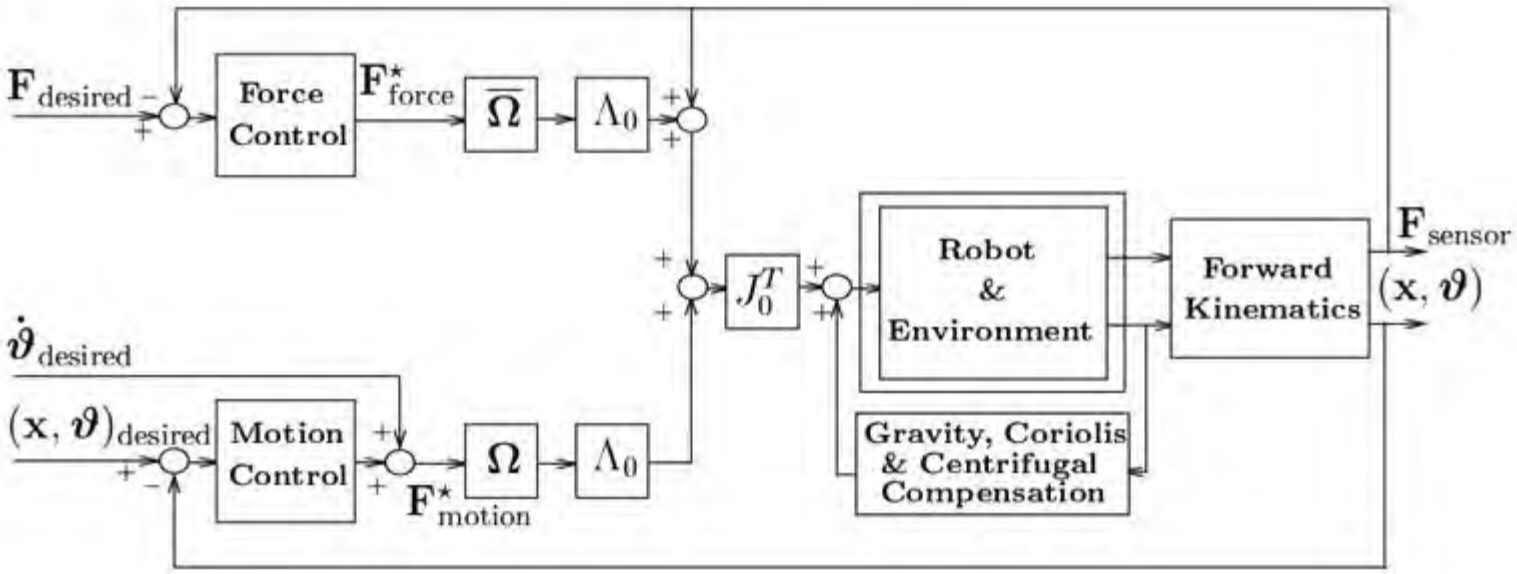
$$F = \Omega F_{motion} + \bar{\Omega} F_{force}$$

Selection matrix



$$\Omega = \begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 0 \end{pmatrix}; \quad \bar{\Omega} = I - \Omega$$

Unified Motion & Force Control



Two decoupled Subsystems

$$\Omega \dot{\vartheta} = \Omega F^*_{motion}$$

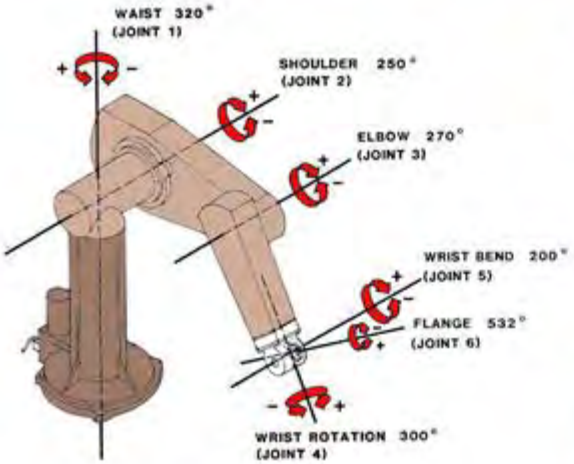
$$\bar{\Omega} \dot{\vartheta} = \bar{\Omega} F^*_{force}$$

Course Evaluation

http://axess.stanford.edu

CS225A - Experimental Robotics

Moved to Fall Quarter



Final Examination

Wednesday
March 19
8:30-11:30am

Jordan Hall,
room 041

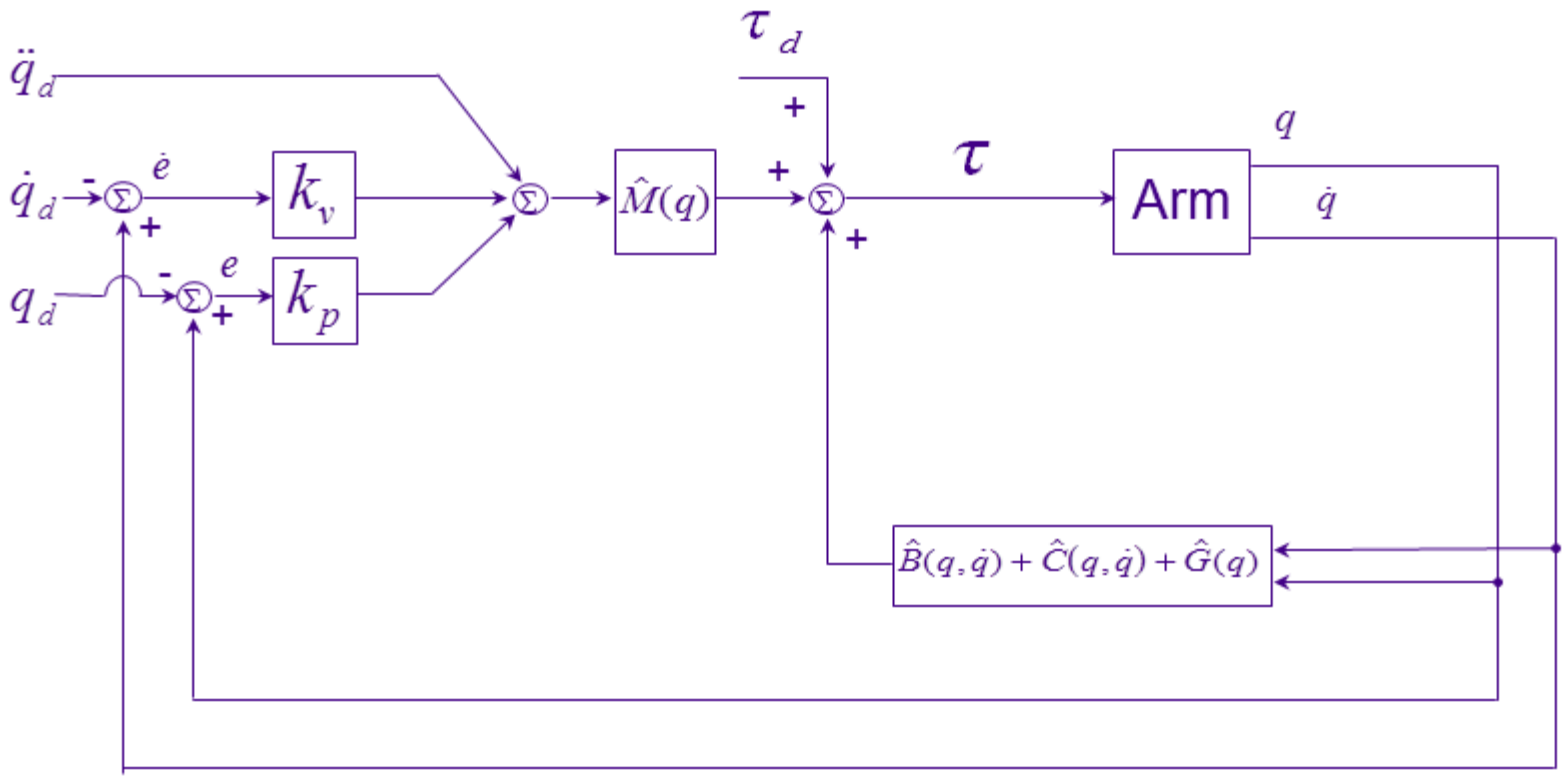
Please be onsite at
8:20am!

Open-book exam

Control

- Natural Systems
- PID Control
- Joint-Space Dynamic Control
- Task-Oriented Control
- Force Control

Joint Space Control



Task-Oriented Control