Video Segment

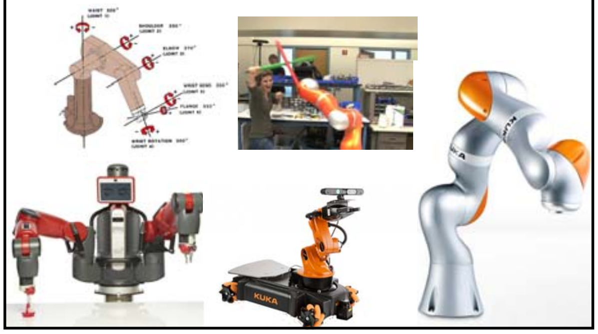
Reach and grasp by people with tetraplegia using a neurally controlled robotic arm, Leigh R. Hochberg *et al.*, nature, 2012

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

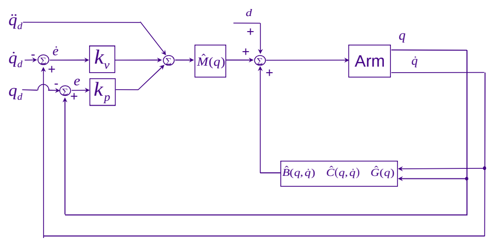
Please be onsite at 8:20am!

Open-book exam

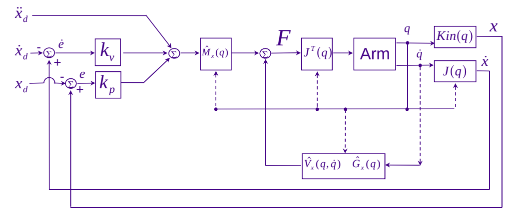
Control

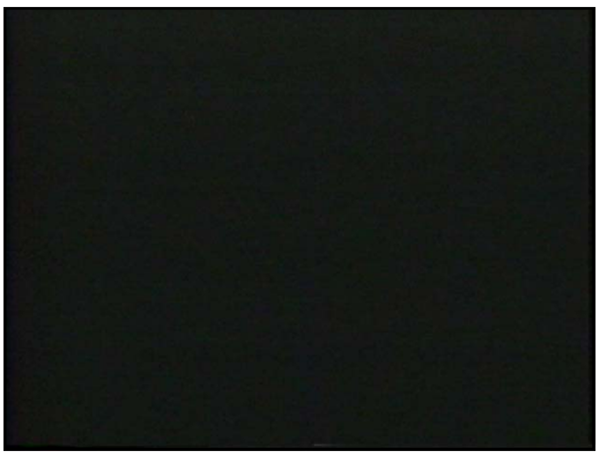
- Natural Systems
- PID Control
- Joint-Space Dynamic Control
- Task-Oriented Control
- Force Control

Joint Space Control

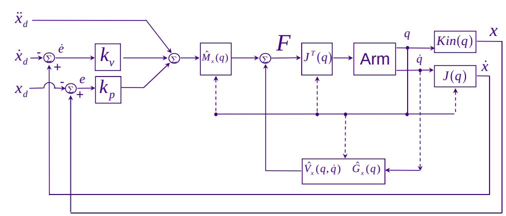


Task-Oriented Control





Task-Oriented Control

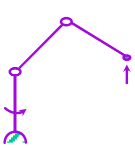


Compliance

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

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

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: $\hat{M}_x k_p' = k_p$

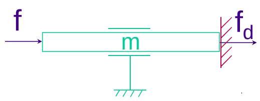
$$F = K_x(x - x_d)$$

$$J^T F \quad J^T K_x \quad x \quad (J^T K_x J) \quad K$$

$$K \quad J^T(\ \ )K_x J(\ \ )$$

Force Control

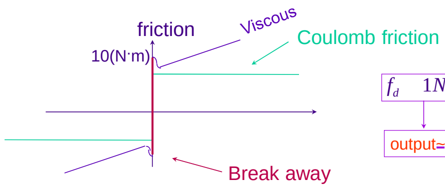
1-d.o.f.



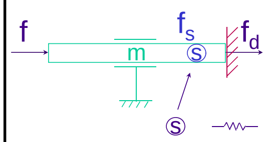
$m\ddot{x} \quad f$

set $f \quad f_d$

Problem



Force Sensing



Ⓢ —w— ; $f_s \quad k_s x$

$m\ddot{x} \quad \underline{k_s x} \quad f$

f_s

At static Equilibrium

$f_s \quad f_d \qquad f \quad f_d$

Dynamics

$m\ddot{x} \quad k_s x \quad f_d \quad f_{Dynamic}$

Dynamics

$m\ddot{x} \quad \underline{k_s x} \quad f$

$\downarrow f_s$

$\frac{m}{k_s}\ddot{f}_s \quad f_s \quad f$

$f_s \quad k_s x$

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

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

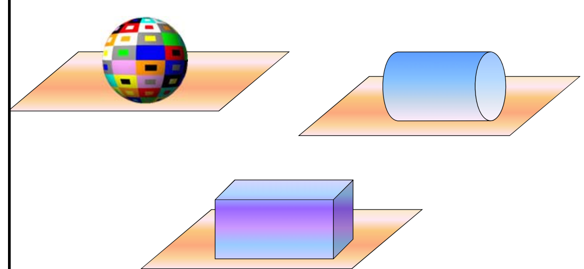
Control

$f_d \quad \frac{m}{k_s}(\; k_{p_f}(f_s \quad f_d) \quad k_{v_f}\dot{f}_s)$

Closed Loop

$\frac{m}{k_s}[\ddot{f}_s \quad k_{v_f}\dot{f}_s \quad k_{p_f}(f_s \quad f_d)] \quad f_s \quad f_d$

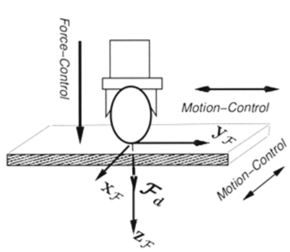
Task Description



Task Specification

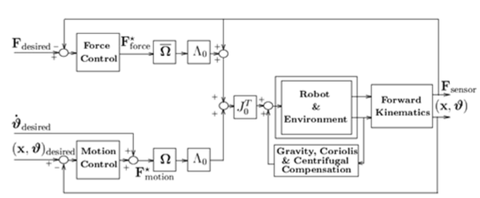
$F = \Omega F_{motion} + \bar{\Omega} F_{force}$

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

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

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