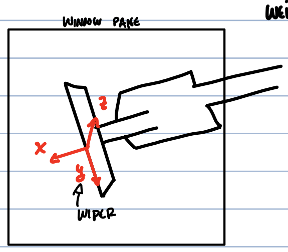
22 Hybrid Control

Control desired position in some dimensions, & desired force in other dimensions

Hybrid position/force control is a systemic way of assigning control modes (position or force) in a non-conflicting way

A way consistent w/ geometric constraints

Ex: Robot wiping a window



We'll assume wiping window is frictionless

Robot gripper

z ⊥ to window

6 DOF robot x, y, z, & rotation

	(velocities) Kinematic constraints	(forces) Static constraints
Natural constraints	$V_z = 0$ $\omega_x = 0$	$f_x = 0$ $f_y = 0$ $\tau_y = 0$ $\tau_z = 0$
Artificial constraints	$V_x = V_{x,des}$ $V_y = V_{y,des}$ $\omega_y = \omega_{y,des} = 0$ $\omega_z = \omega_{z,des} = 0$	$f_z = F_{z,des}$ $\tau_x = \tau_{x,des} = 0$

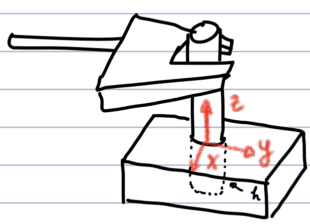
All 6 DOF accounted for

Identifies where we want to control things

All 6-DOF need to be accounted for in each row and column

If we aren't controlling f_x or f_y, then any friction will add as a disturbance, so a good set of PD gains will overcome any error

Ex: Robot pulling a peg out of a hole



	(velocities) Kinematic constraints	(forces) Static constraints
Natural constraints	$V_x = 0$ $V_y = 0$ $\omega_x = 0$ $\omega_y = 0$	$f_z = 0$ $\tau_z = 0$
Artificial constraints	$V_z = V_{z,d}$ $\omega_z = \omega_{z,des} = 0$	$f_x = f_{x,des} = 0$ $f_y = f_{y,des} = 0$ $\tau_x = \tau_{x,des} = 0$ $\tau_y = \tau_{y,des} = 0$
	Position control	Force control

Assume the peg slides without friction and the peg is weightless

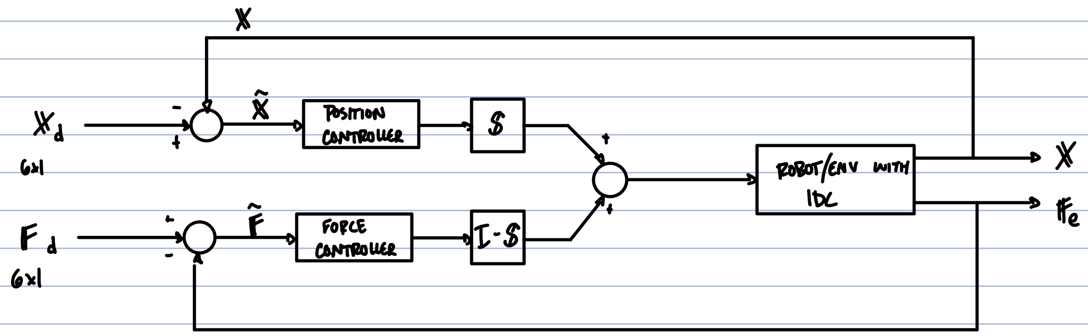
How to form a hybrid controller:

Make a binary selection matrix: 1 = position control, 0 = force control

e.g. peg in hole task

$$\sigma = \begin{array}{c} \left[\begin{array}{cccccc} 0 & 0 & 1 & 0 & 0 & 1 \end{array}\right] \\ \begin{array}{cccccc} x & y & z & x & y & z \end{array} \\ \text{translation} \qquad \text{rotation} \end{array}$$

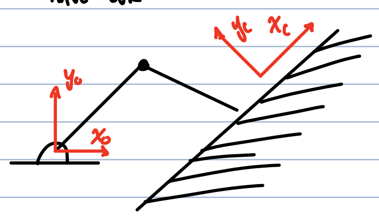
$\mathbb{S}$ = SELECTION MATRIX = $\operatorname{diag}(\sigma)$



WHAT IF THE CONSTRAINT FRAME IS ROTATED/TRANSLATED RELATIVE TO THE ROBOT (BASE) FRAME OF REFERENCE?

EX: 2-DOF ROBOT IN CONTACT W/ ANGLED SURFACE

WE HAVE OUR



	(VELOCITIES) KINEMATIC CONSTRAINTS	(FORCES) STATIC CONSTRAINTS
NATURAL CONSTRAINTS	${}^{c}V_y = 0$	${}^{c}f_x = 0$
ARTIFICIAL CONSTRAINTS	${}^{c}v_x = v_{x,d}$	${}^{c}f_y = f_d$

$${}^{c}\mathbb{X} = {}^{c}\mathbb{R}_0 \; {}^{0}\mathbb{X}$$

${}^{c}\sim$ = CONSTRAINT FRAME

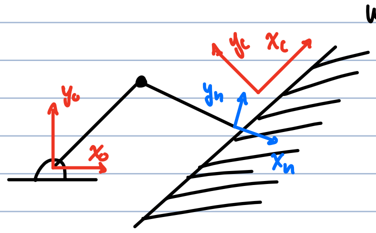
OR

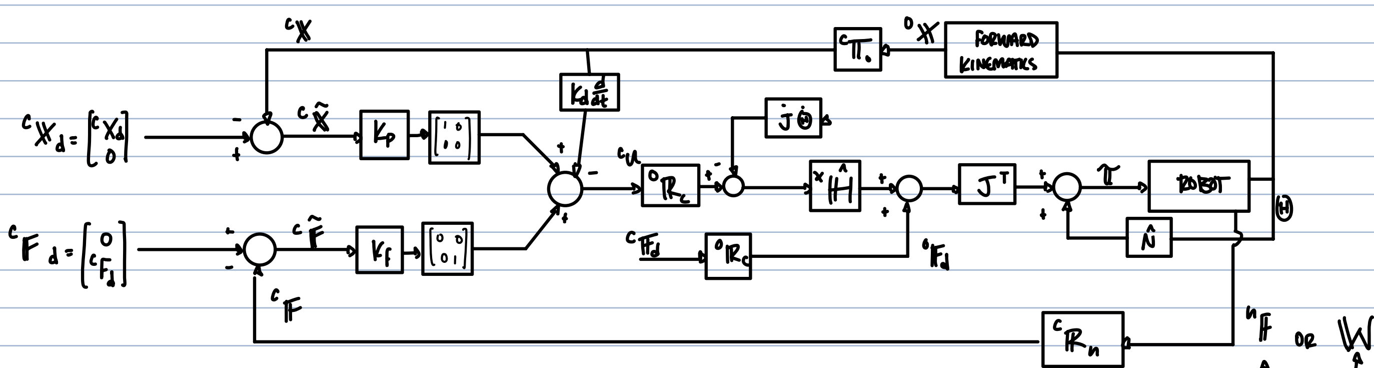
$${}^{c}\mathbb{X} = {}^{c}\mathbb{T}_0 \; {}^{0}\mathbb{X}$$

$${}^{c}\mathbb{F} = {}^{c}\mathbb{R}_0 \; {}^{0}\mathbb{F}$$

$${}^{c}\mathbb{F} = \underbrace{{}^{c}\mathbb{R}_0 \; {}^{0}\mathbb{R}_n}_{{}^{c}\mathbb{R}_n} \; {}^{n}\mathbb{F}_{SENSOR}$$

WHAT IF WE ADDED A FORCE SENSOR?





6x1

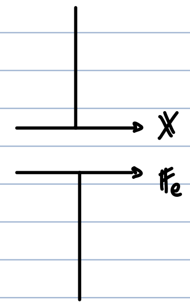
J^T_{nc} IS WRENCH

NOT n

FORCE SENSORS ARE NOISY, SO WE SHOULDN'T USE DERIVATIVE CONTROL

$\Rightarrow$ USE VELOCITY CONTROLLERS

ROBOT/ENV WITH IDC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