

Force Control of a *Non-backdrivable* Robot *Without* a Force Sensor

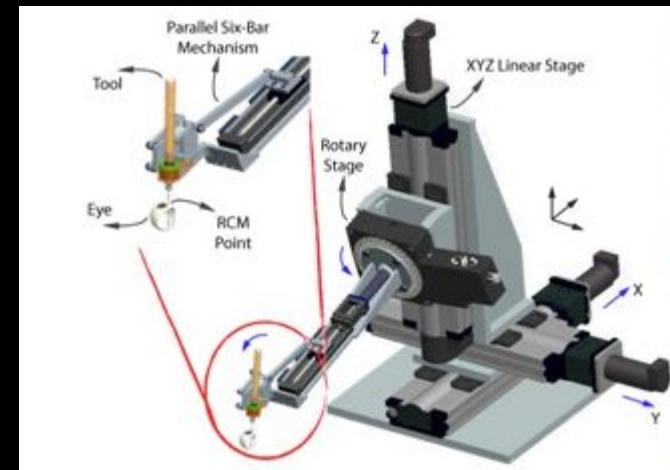
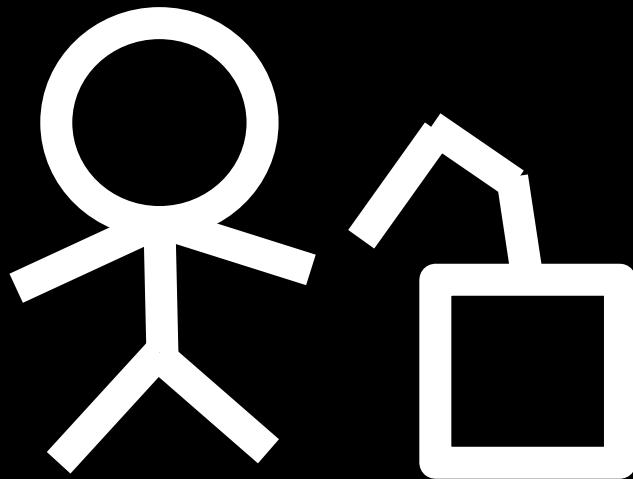
Zihan Chen and Peter Kazanzides
Johns Hopkins University, Baltimore MD, USA

DEMO



XY Stage
Non-backdrivable
Lead screw
NO Force Sensor

The Story



JHU Eye Robot 2

Image: <https://ciis.lcsr.jhu.edu/dokuwiki/doku.php?id=research.eyerobots>

Non-backdrivable

Backdrivable



Geomagic® Touch™

- **Non-backdrivable** joints prevent any motion in the event of power failure, ensuring total stability

Non-Backdrivable



RENISHAW

From
neuro | mate datasheet

Move a Robot

Backdrivable



MOVE IT

Non-Backdrivable



Move a Non-backdrivable Robot

- Master/Slave
 - e.g. 3D Space Mouse
- Force Sensor

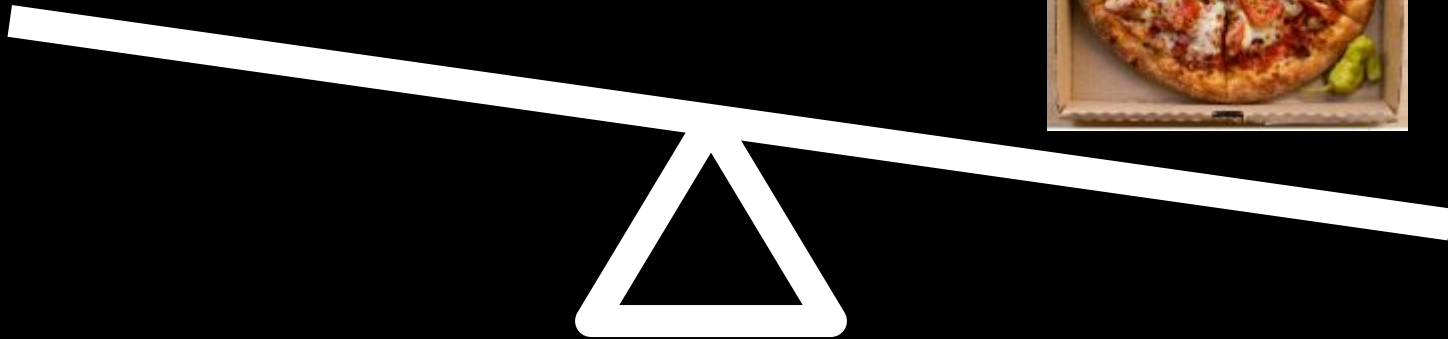


3DCONNEXION

500



= \$5K =



Force Control of a *Non-backdrivable* Robot *Without* a Force Sensor

Previous Work

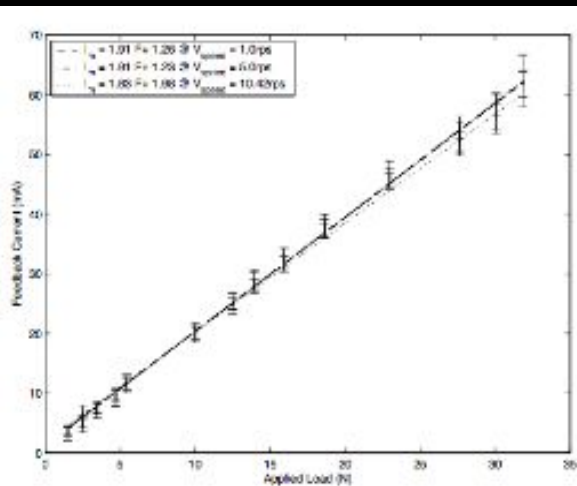


Fig. 9. Current Feedback Performance

A. Kapoor et al. 2004

Because the system is non-backdriveable, the force estimation only works if the controller is actively trying to move the motor. It is interesting to note, however, that the force estimate is accurate even when the motor is moving slowly (Figure 9) or not at all (stall case, Figure 10). This suggests that it would be possible to obtain force feedback from motor currents in a non-backdriveable system with an appropriate control law. We plan to investigate this in our future work.

A. Kapoor et al. 2004

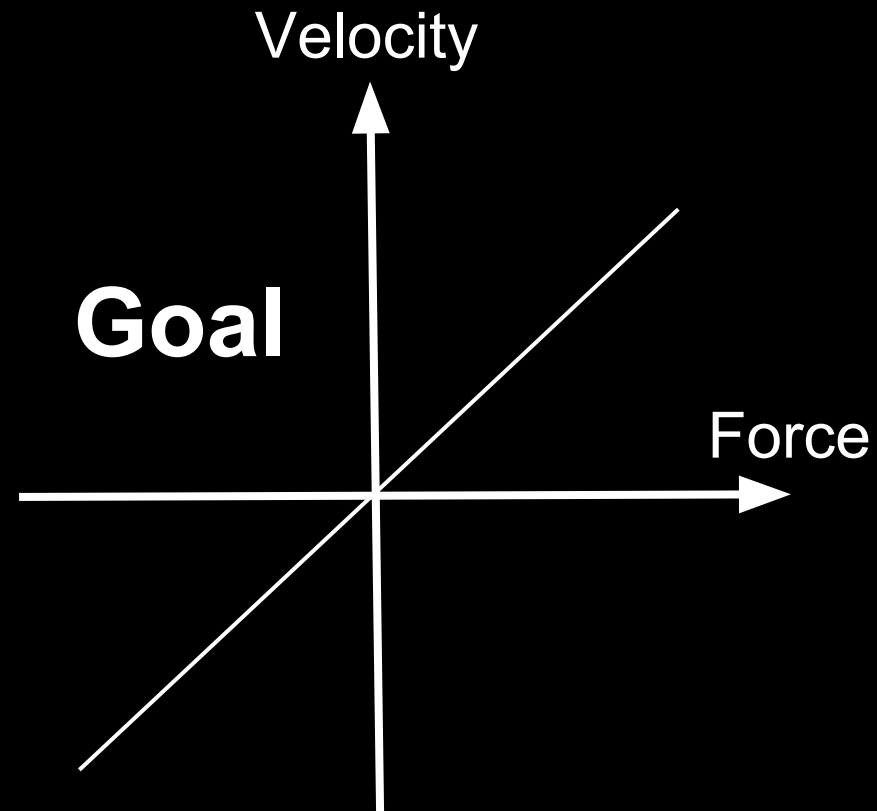
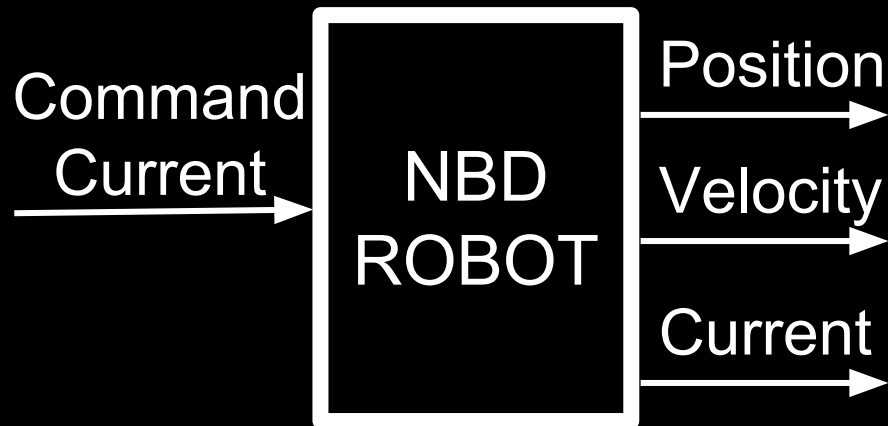
Hardware



Leadscrew
(20 cm x 20 cm)



Goal

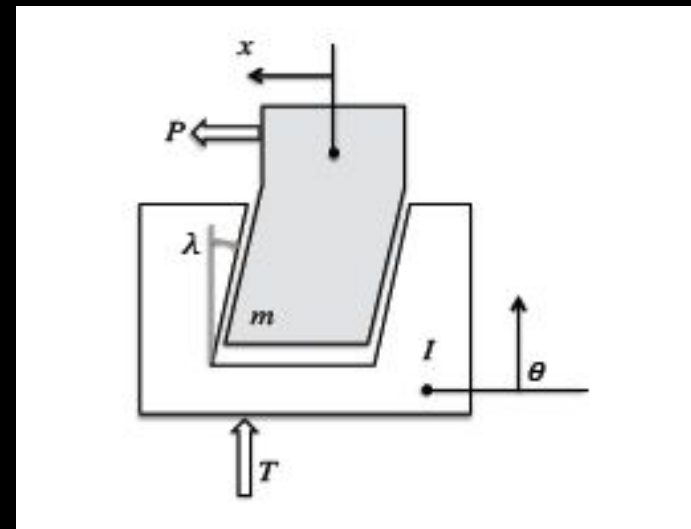


Admittance Like Control

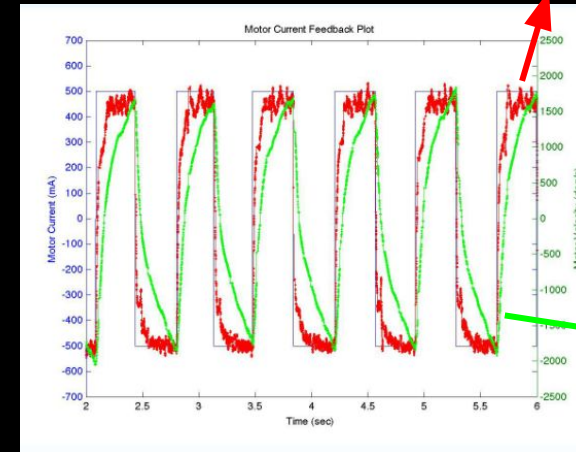
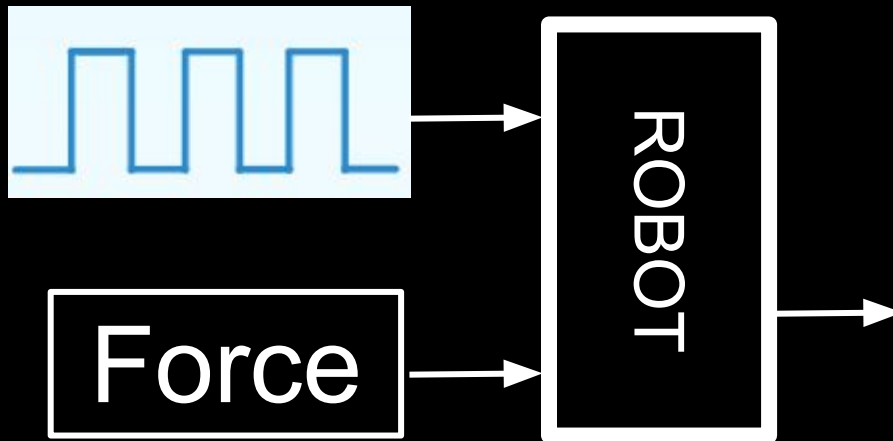
- Force direction
- Change speed

Why NOT Model Based Solution?

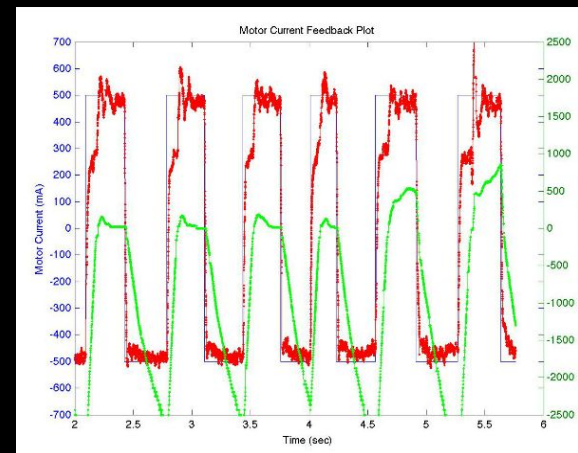
1. Lead screw model
 - NO unique solution
2. Current feedback noise
3. Bad acceleration measurement
 - No tachometer installed
 - Bad synchronization



Maybe an Experimental Way ?

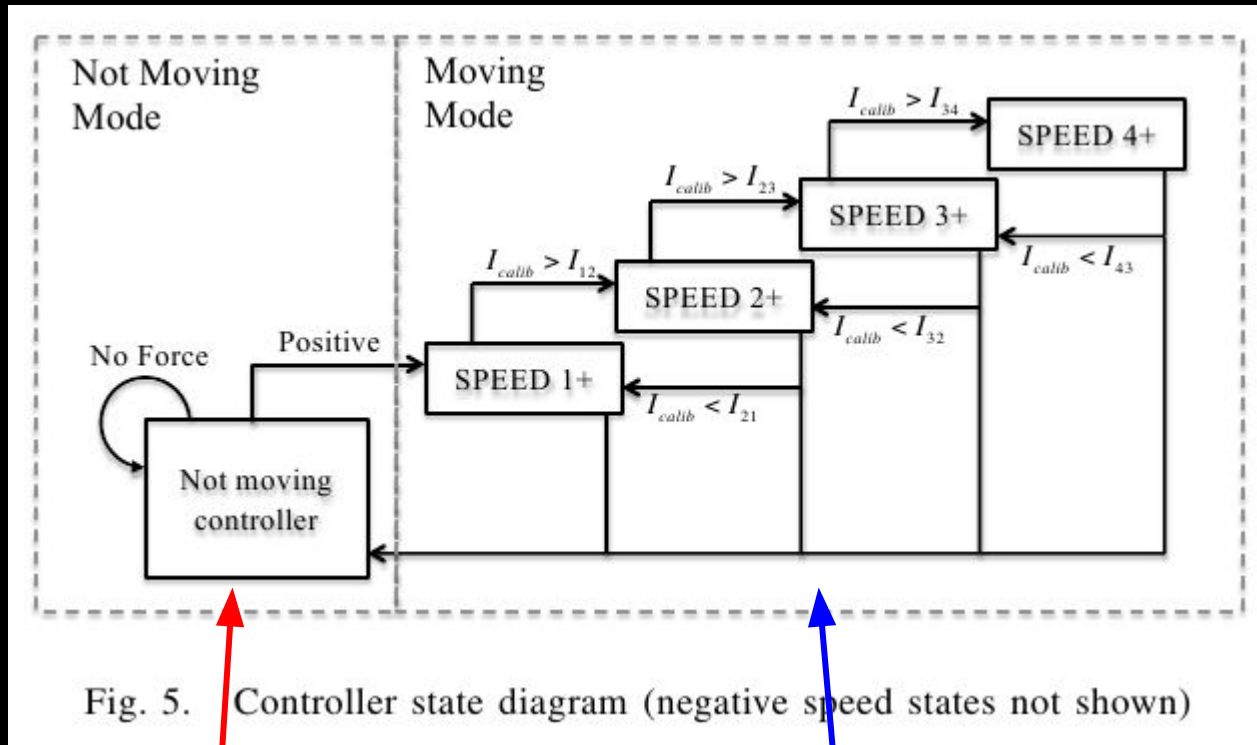


No Force



Negative Force

Solution

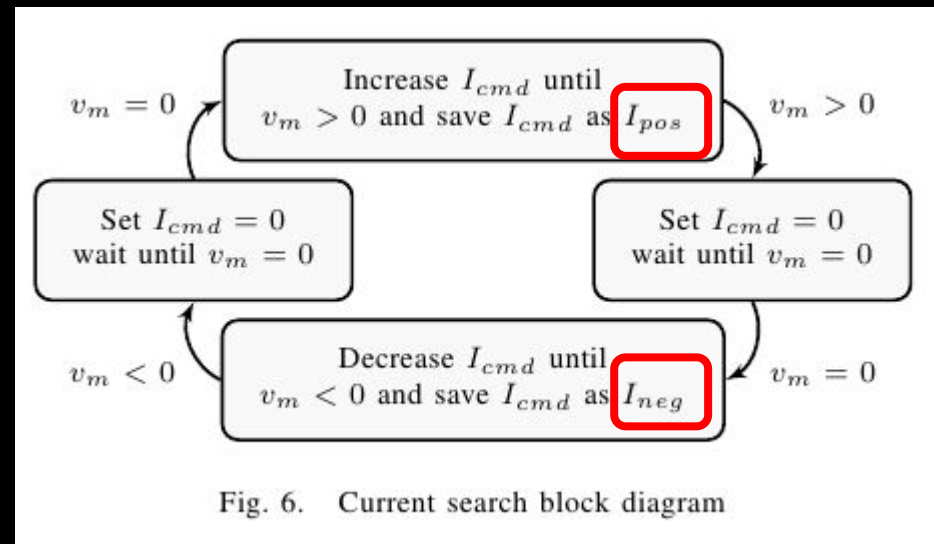
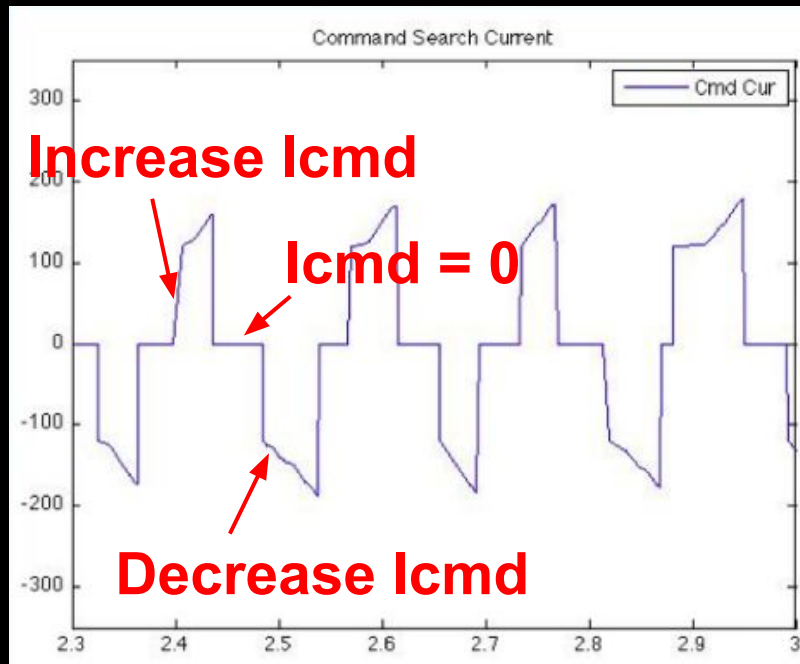


Direction

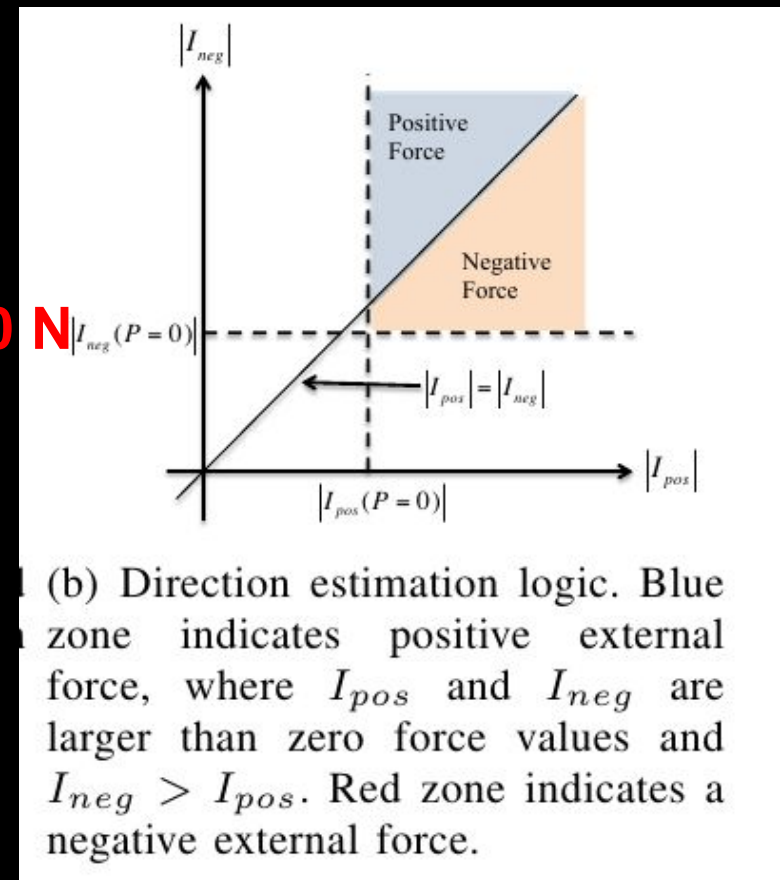
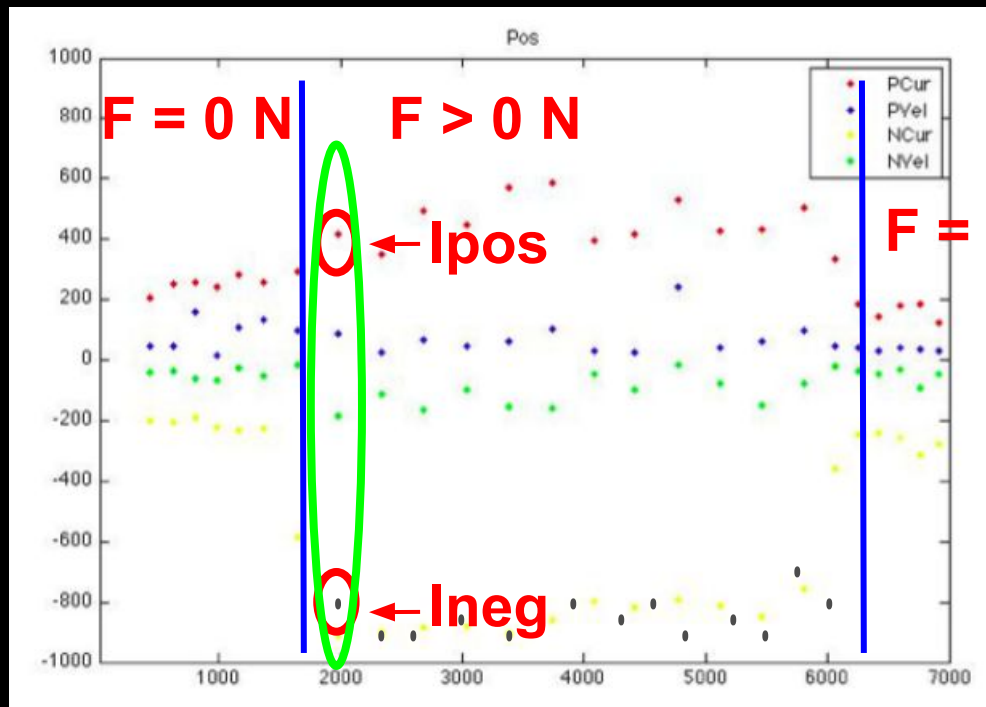
Speed

Direction

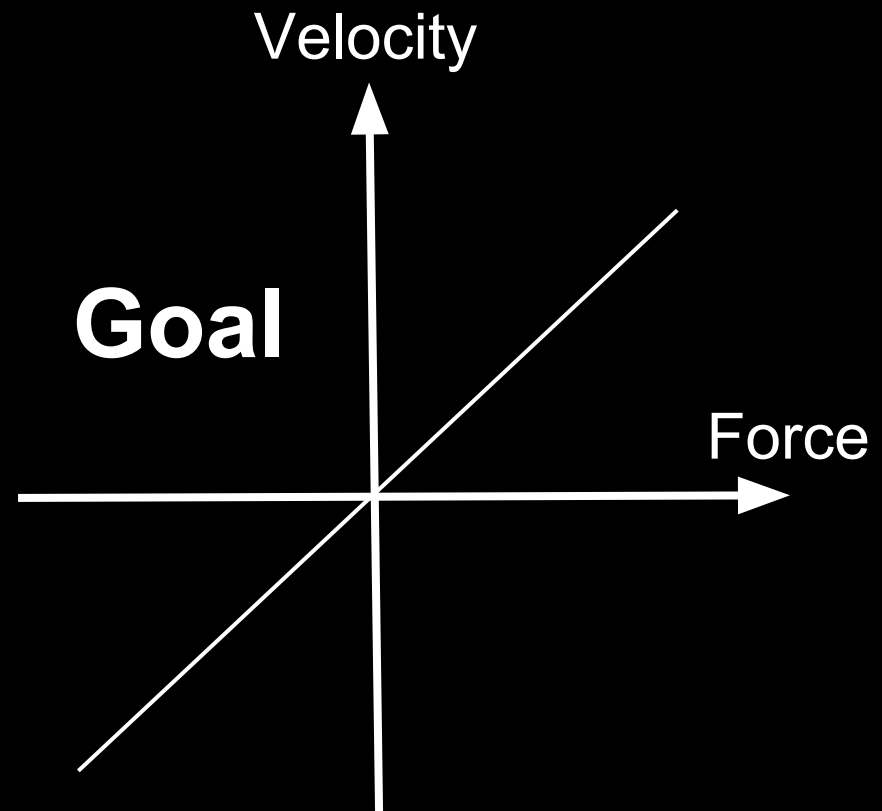
Force Direction (Dithering)



Force Direction (Dithering)



Speed



Force Magnitude

PM DC Motor

$$T_m = K_T \cdot I_m$$

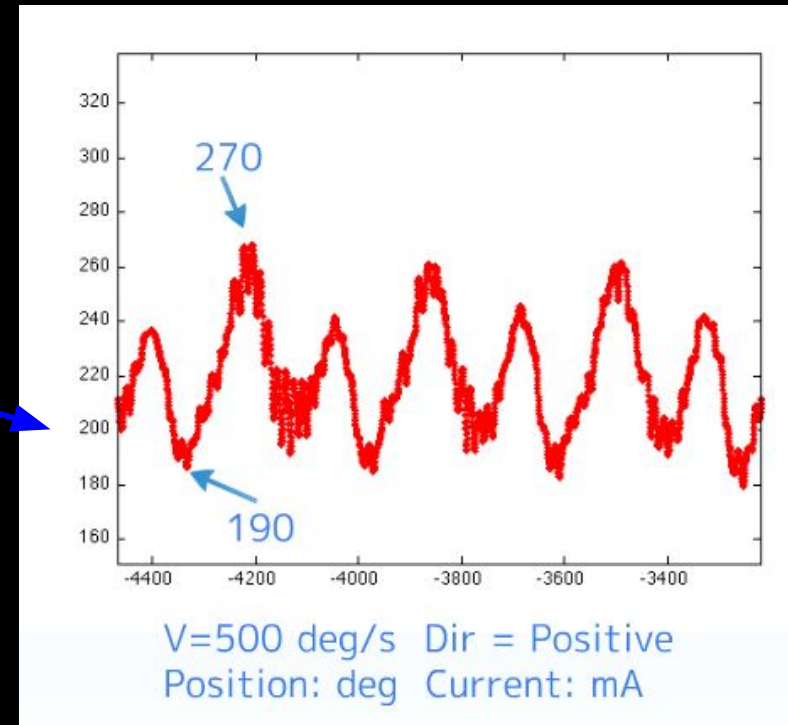
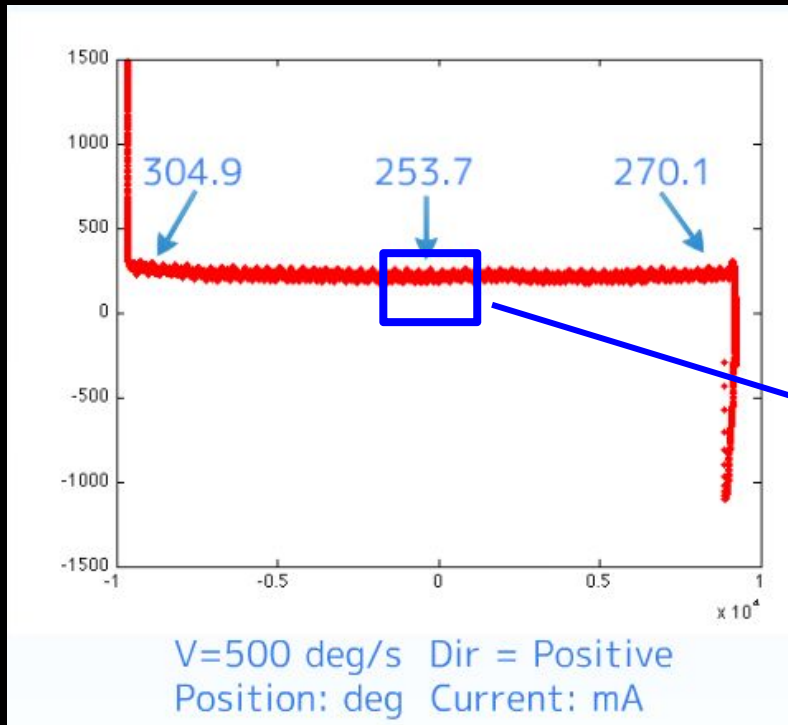
$$T_m = I \ddot{\theta} + T_f + T_L$$

$$T_L = f(N) = f(P)$$

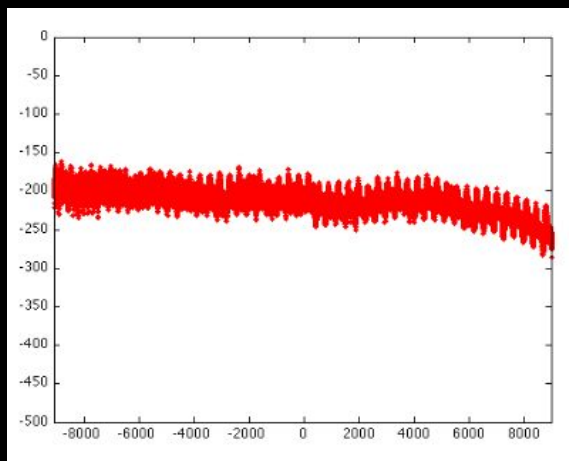
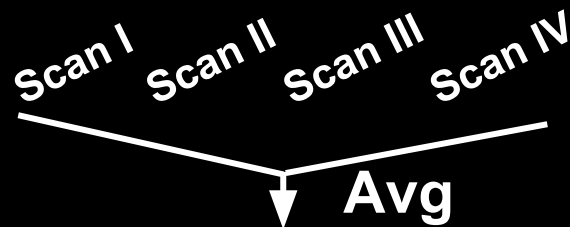
$$K_T \cdot I_m = I \ddot{\theta} + T_f + f(P)$$

$$\ddot{\theta} = 0$$

Calibration (Why)

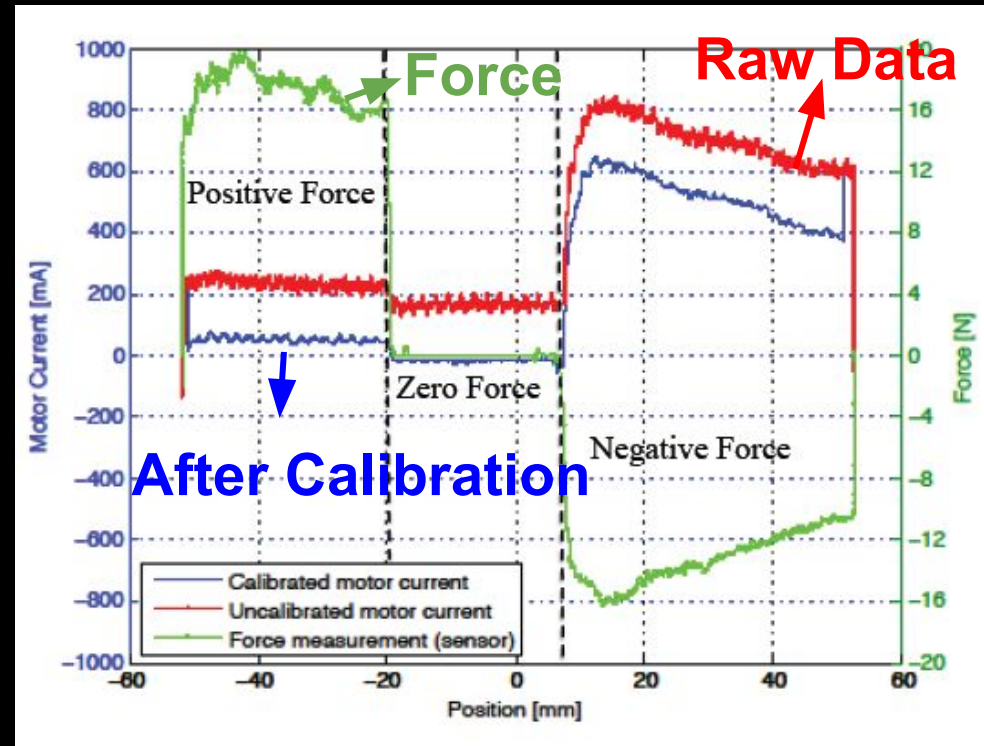


Calibration (How + Result)



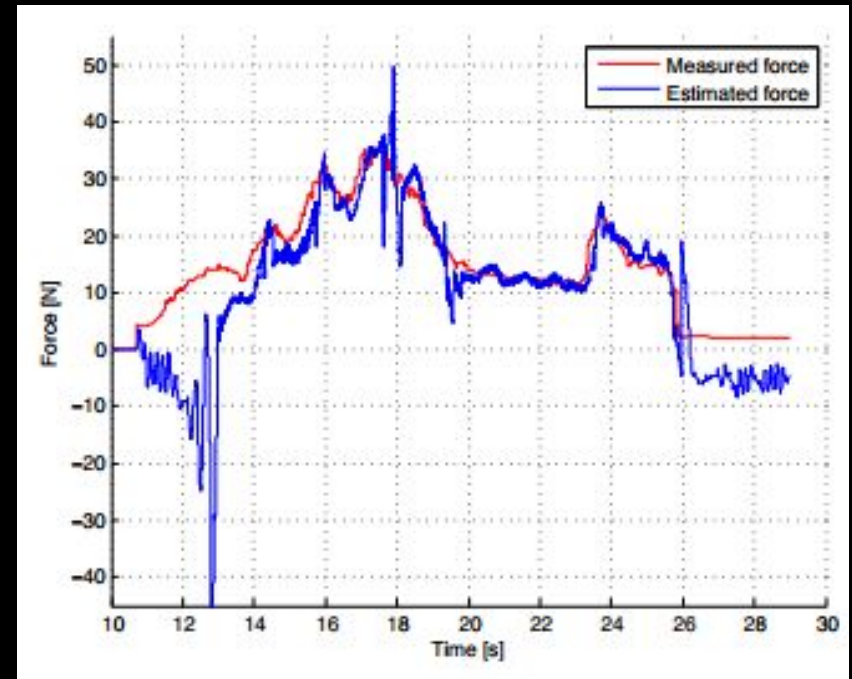
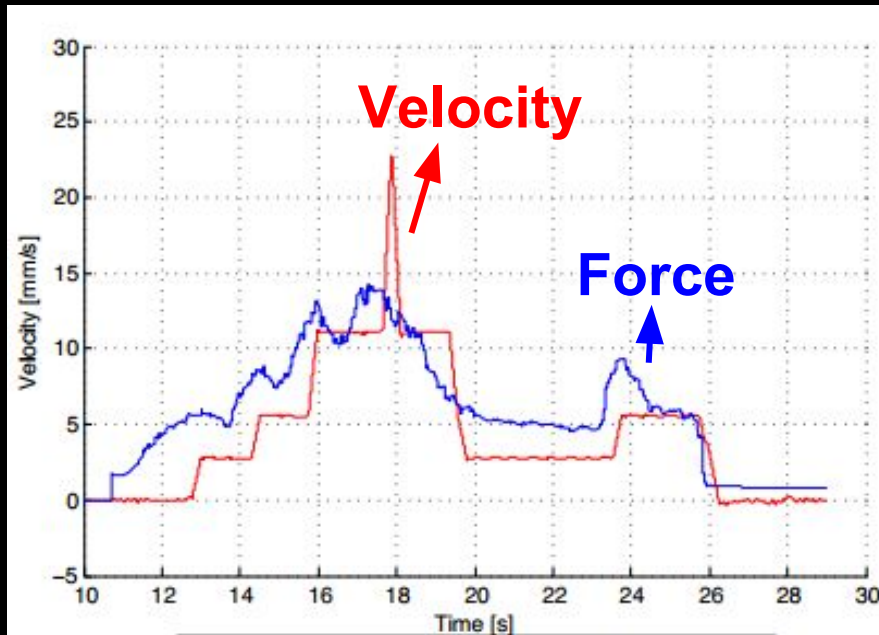
4 Scan for 1 Speed
Level

16 x 2 Scans in Total

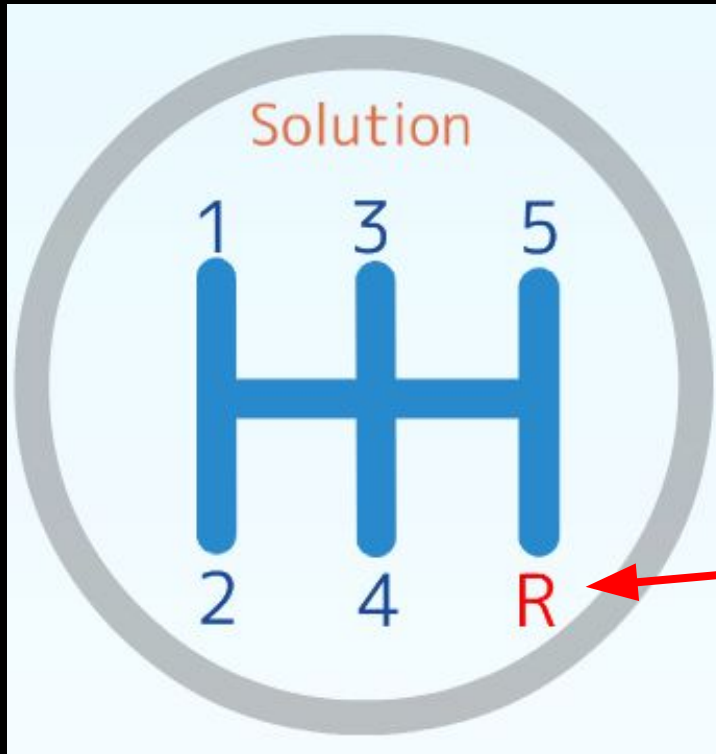


Result: $V = 500 \text{ deg/s}$

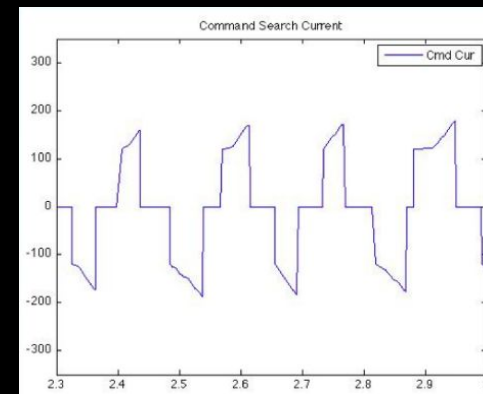
Speed Change



Solution Summary



Dithering



Conclusion & Future work

- Force control solution
 - Non-backdrivable
 - No Force Sensor
- Future work
 - Extend to Multi-axes Robot
 - Continuous Speed Change

Thank You !

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