Manipulator System Based on Compliance Control For Object Manipulation

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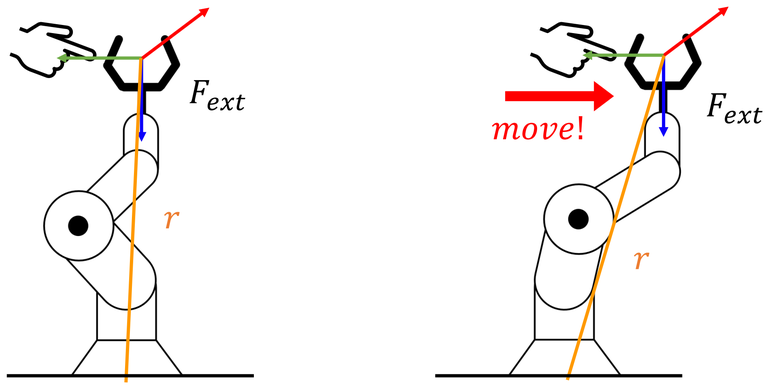
I. Introduction

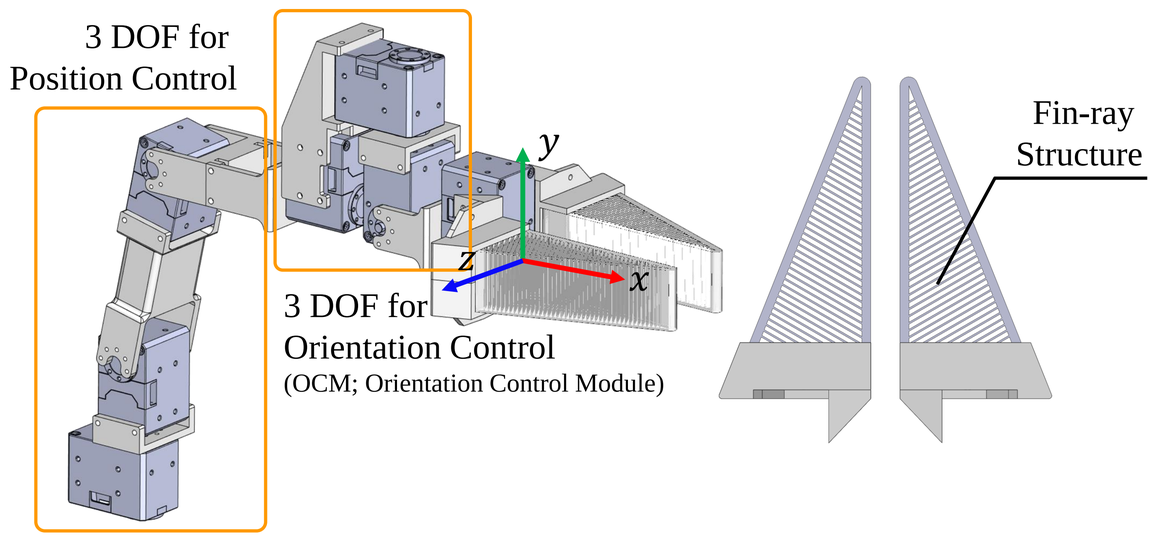


Objective

1) Robotic manipulation with only low-cost servo motors without F/T sensor
2) Stable interaction with external objects
3) Stable response to external disturbance

Keywords Admittance Control, Force estimation, Soft gripper, Low-cost Sensor

II. Hardware



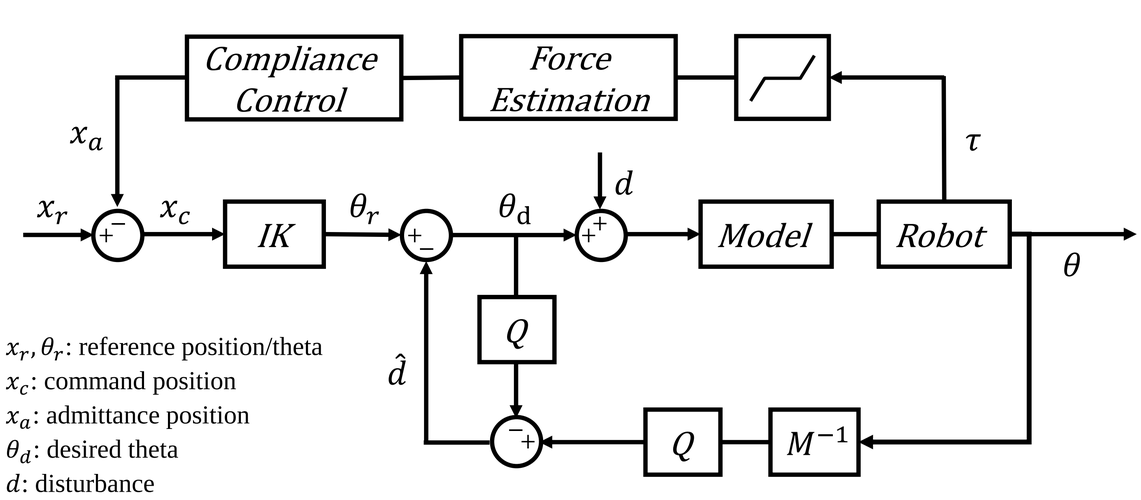
Manipulator Design

1) 3 DOF position control + 3 DOF orientation control (OCM)
2) Fin-ray soft gripper to increase flexibility in interaction with external objects

OCM (Orientation Control Module)

1) The axes of the three servo motors intersect at one point
2) Enhances control efficiency and enables ease of force estimation

III. Control



Control System DOB, External Force Estimation, Position Based Compliance Control

IV. Conclusion

In this study, a compliant manipulator was studied to facilitate object manipulation with only a low-cost servo motor. Based on the configured system, the stability will be verified by testing the operation of combining on top of the drone and replacing the light bulb into the socket through aerial manipulation.

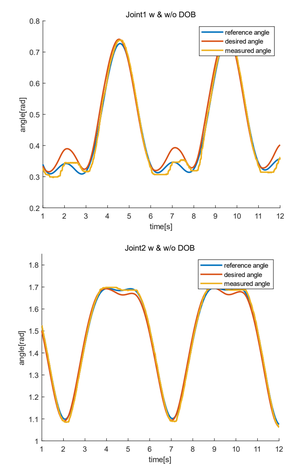
III. Control (contd.)

[DOB]

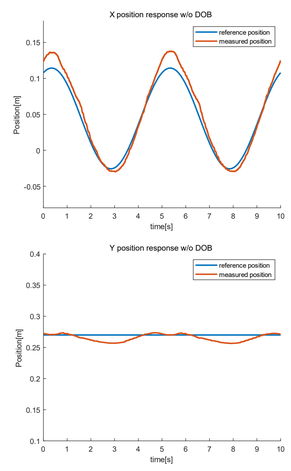
Issue) Impossible to know the gravity matrix for compensation when an unspecified load is applied to the end-effector

Solution) Apply DOB to each servo motor to improve the robustness of the servo angle control

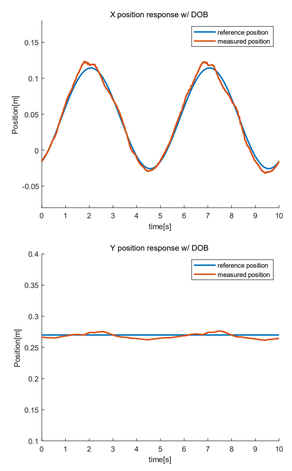
Joint Response w/ & w/o DOB



Position Response w/o DOB



Position Response w/ DOB



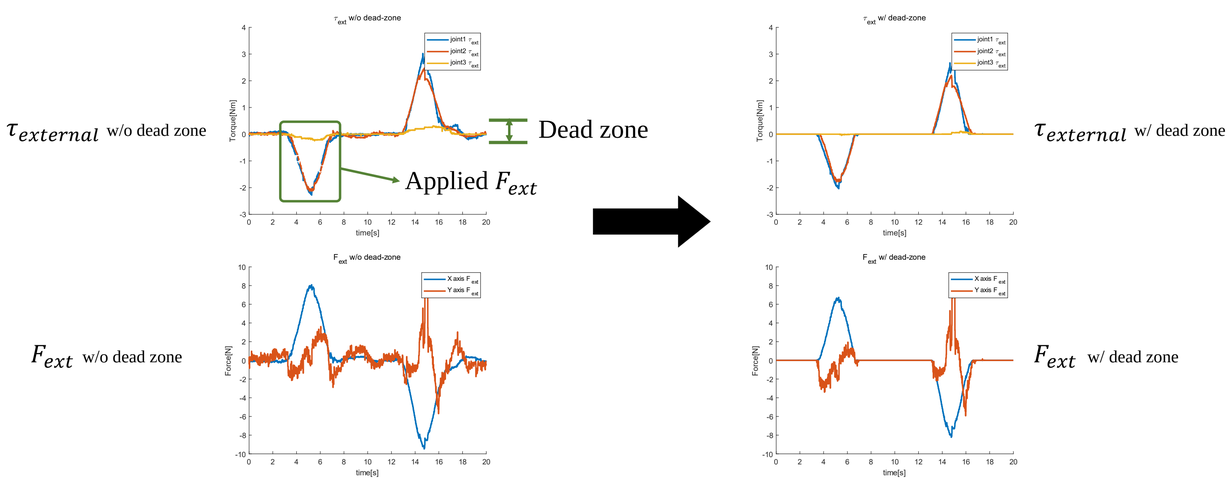
Result

1) Compensate for stiction and gravitational sagging phenomena
2) Improved position tracking performance of low-cost servo motor
3) Model-free characteristic that allows robust position control in any disturbance

[External Force Estimation]

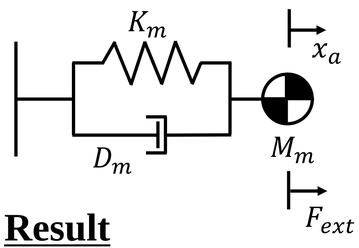
1) Set uncertain region to dead-zone to reduce force estimation error
2) Admittance control in dead-zone → inherent admittance of the hardware itself

Ideal: $\tau_{external} = \tau_{measured} - \tau_{gravity} = \begin{cases} 0 & if\ F_{ext} = 0 \\ \tau_{external} & if\ F_{ext} \neq 0 \end{cases}$



[Admittance Control (Position-based Compliance Control)]

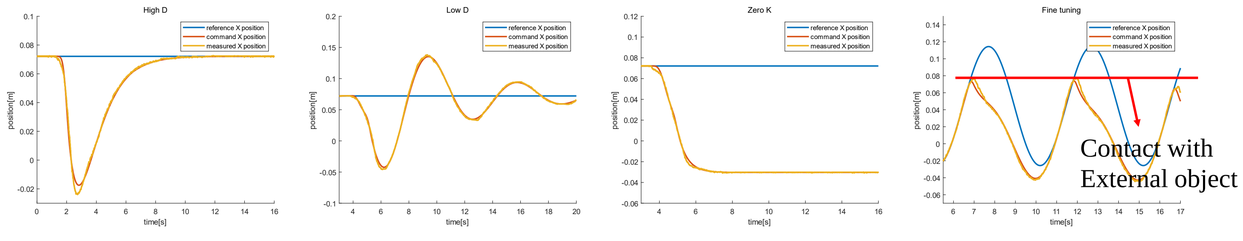
1) Set a virtual mass-spring-damper system for compliant control
2) Admittance performance to external objects despite being a low-cost motor



$$M_m(\ddot{x} - \ddot{x_d}) + D_m(\dot{x} - \dot{x_d}) + K_m(x - x_d) = F_{ext}$$

Result

1) **Flexible response to disturbance**
2) **Stable interaction with external environment**



High D
(M: 1.5, D: 3, K: 1.5)

Low D
(M: 1.5, D: 0.5, K: 1.5)

Zero K
(M: 1.5, D: 3, K: 0)

Fine tuning
(M: 1.5, D: 1.5, K: 1)