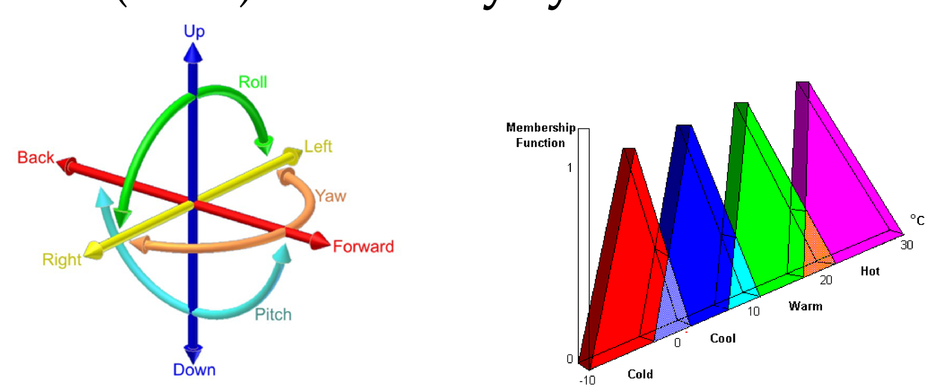
Multi-Input Multi-Output (MIMO) Adaptive Control of 9-DOF Hyper-Redundant Robotic Arm

Xingsheng Xu, Advisor: Raúl Ordóñez

School of Electrical and Computer Engineering University of Dayton

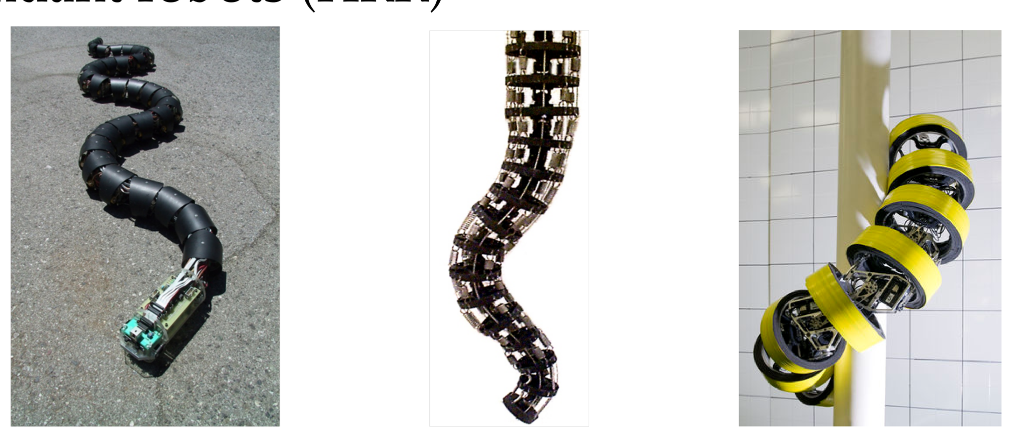
Key Words

- **Degree of freedom** (DOF) and **Fuzzy system**



(a) Degree of freedom (b) Fuzzy system

- **Hyper-redundant robots** (HRR)

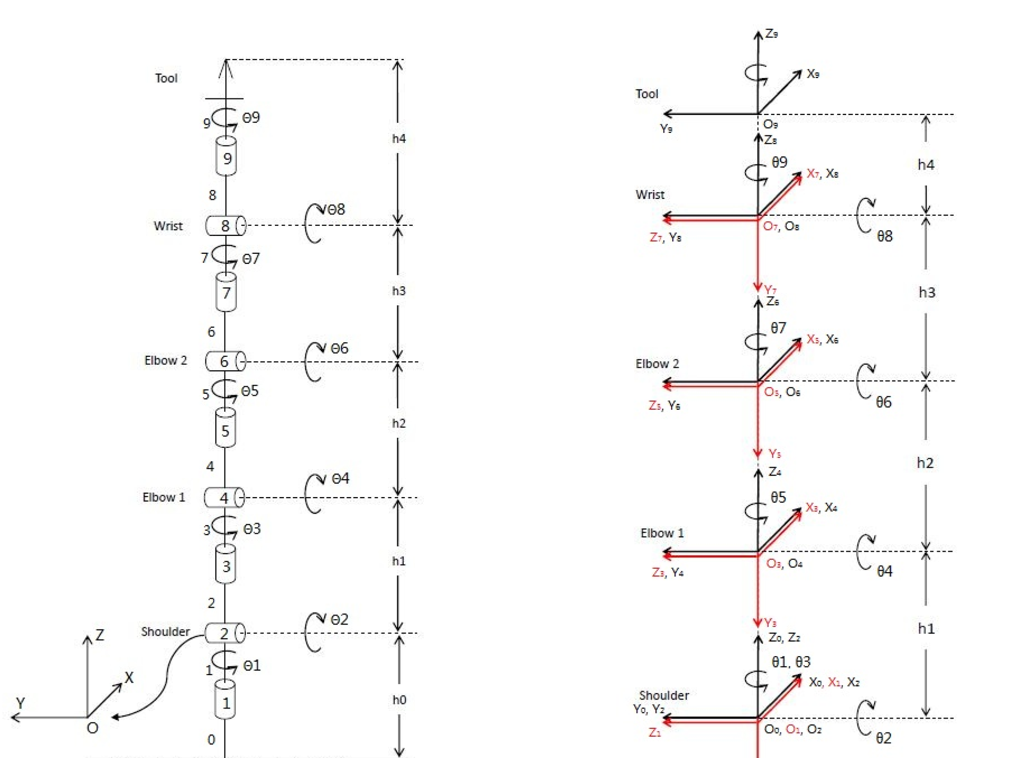


(a) Snake (b) Elephant trunk (c) Tentacle

Objective

- Design both the kinematic and dynamic model of a 9-DOF hyper-redundant arm;
- Apply MIMO adaptive controllers to control the end-effector of the arm in work space.

Kinematic Model



(a) Joint schematic (b) Frame assignment

Dynamic Model

- **Manipulator Jacobian Matrix**: An expression to connect angular velocity ω_n^0, linear velocity v_n^0 of the end-effector and joint velocity $\dot{q}$ as

$$\omega_n^0 = J_\omega \dot{q},$$
$$v_n^0 = J_v \dot{q},$$

where J_ω and J_v are $3 \times n$ matrices.

- **Euler-Lagrange Equation**:

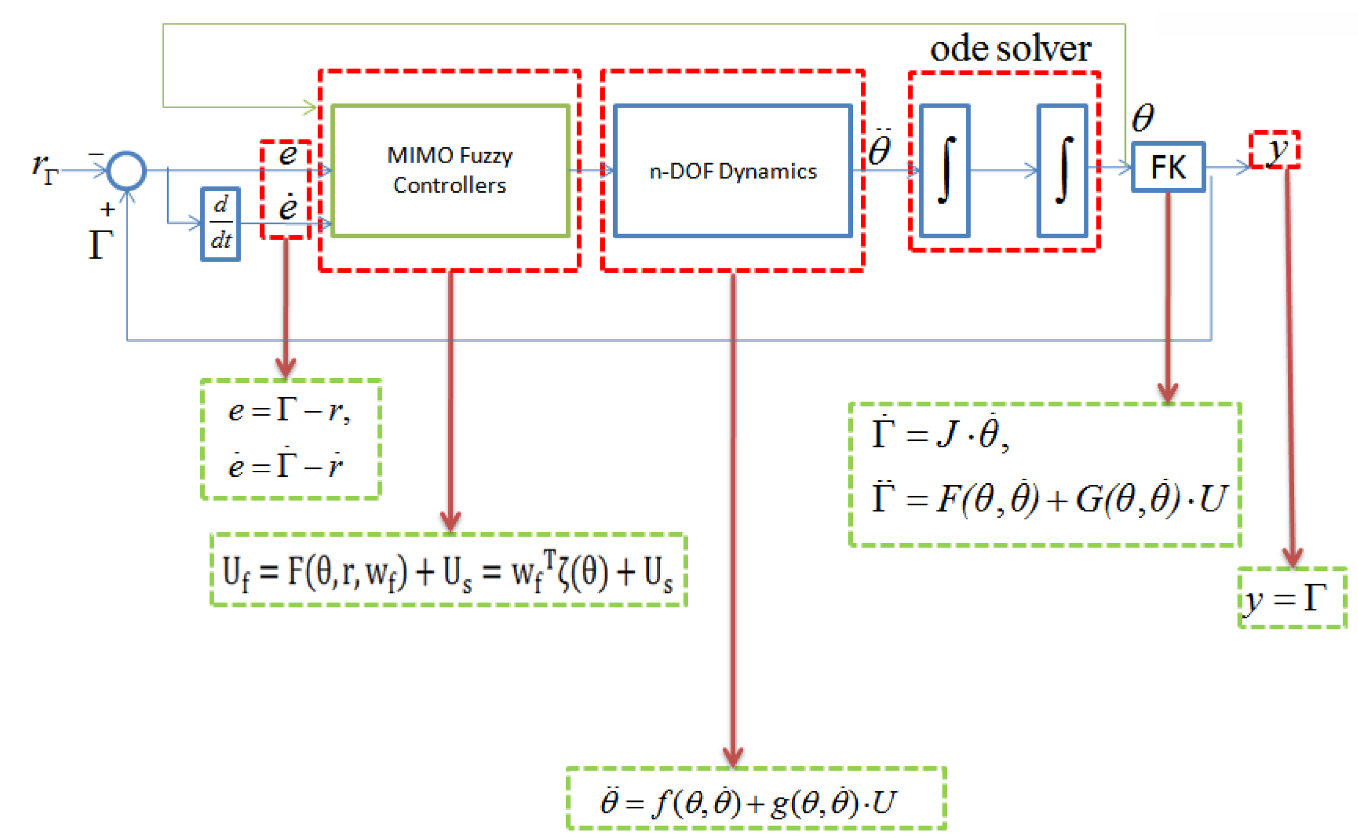
$$\frac{d}{dt}\frac{\partial L}{\partial \dot{q}_i} - \frac{\partial L}{\partial q_i} = \tau_i, i = 1, \ldots, n,$$

where τ_i is input torque of each motor and the Lagrangian L is given by

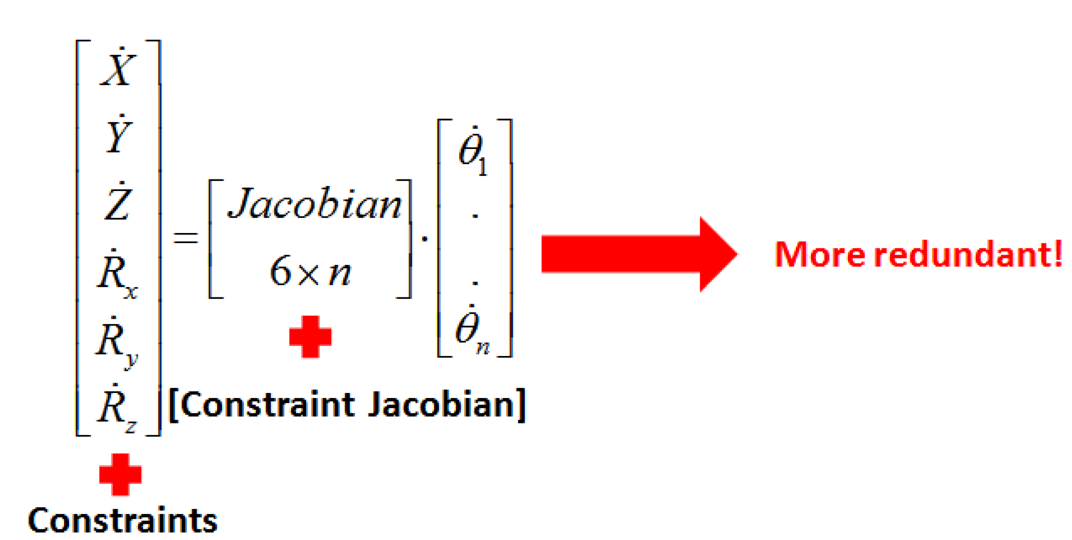
$$L = K - P,$$

where K is the kinetic energy and P is the potential energy.

MIMO Adaptive Control in Workspace

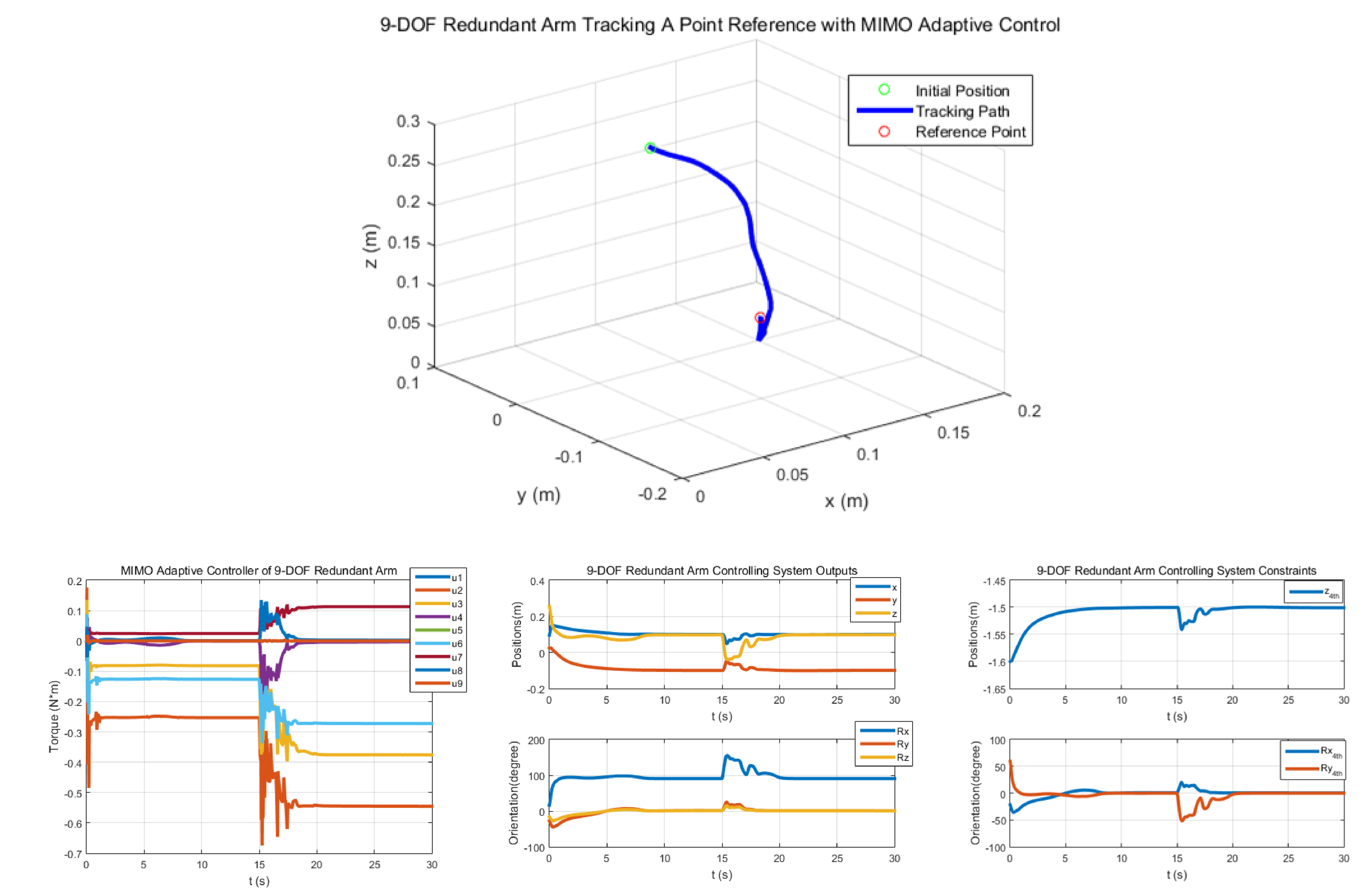


Extra Constraints



Simulation Results

- 9-DOF Arm Tracking and Disturbance Simulation

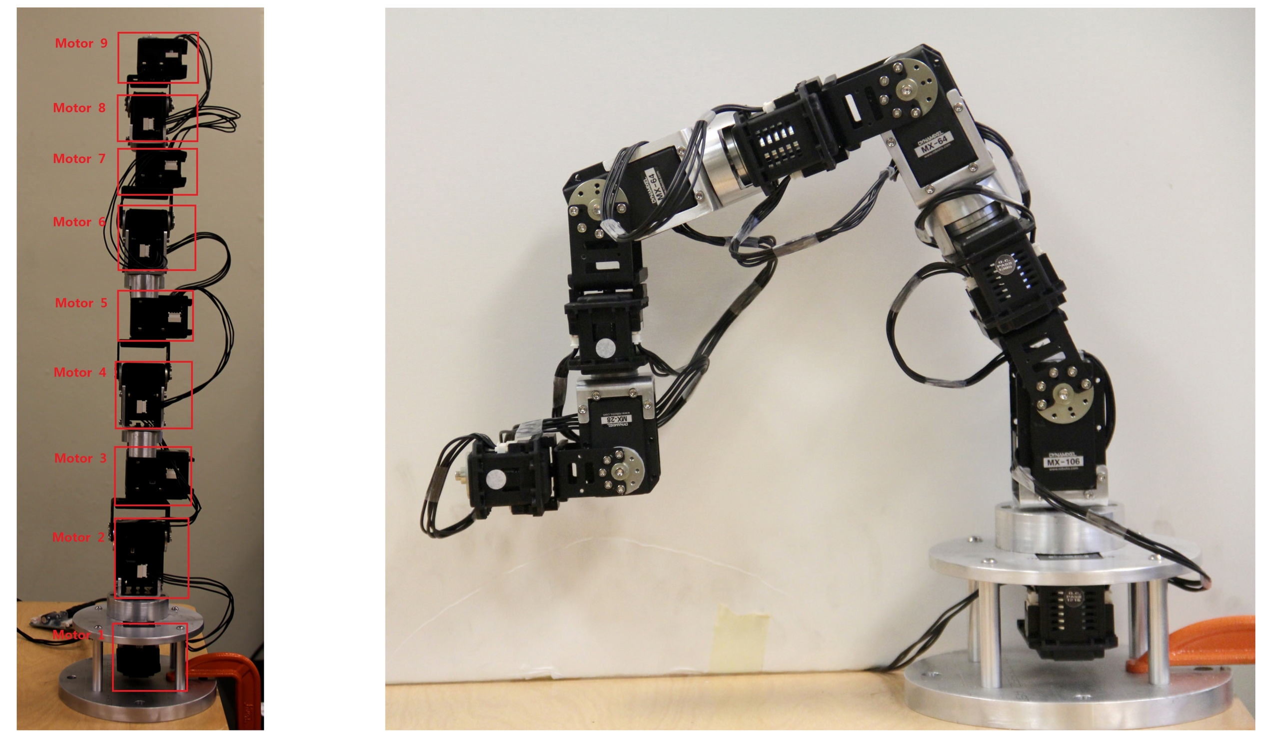


(a) Controllers (b) Outputs (c) Constraints

Conclusion

- Take care of the system nonlinearity and uncertainty;
- Approximate the ideal controller online to the particular system;
- Adjust itself and try to track the reference again after having system disturbance.

Real 9-DOF Arm Platform



(a) Home position 1 (b) Home position 2