

# Cart-Pendulum system stabilization via MPC control schemes

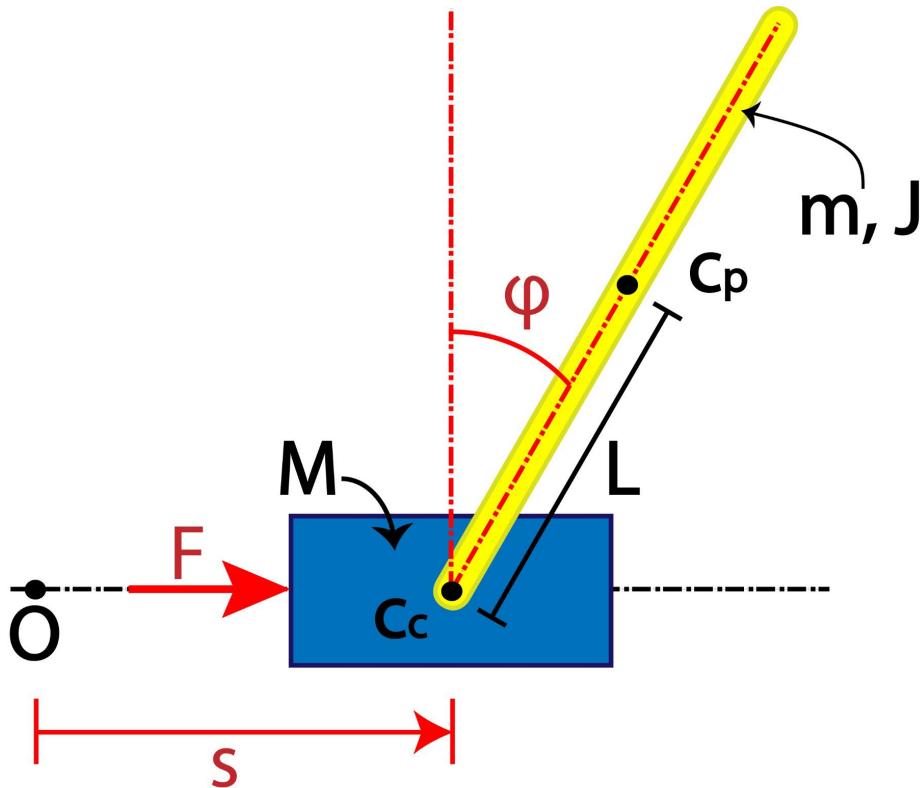
---

JUAN AUGUSTO PAREDES SALAZAR

JPAREDES@UMICH.EDU

# Cart-Pendulum System

---



States:  $x = [s \quad \dot{s} \quad \varphi \quad \dot{\varphi}]^T$

Input:  $u = F$

Parameters:  $m, M, L, J$

Two equilibrium points:

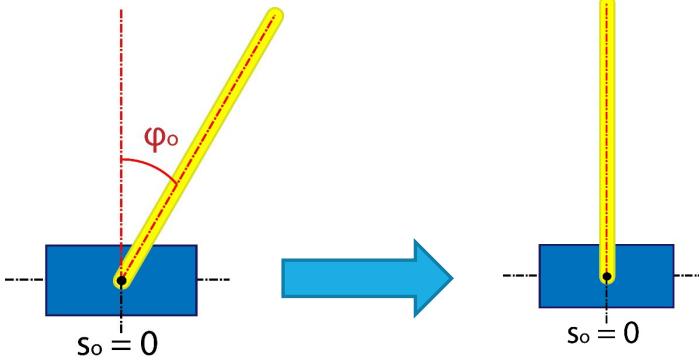
- Upwards unstable position ( $\varphi = 0$ )
- Downwards stable i.s.L. position ( $\varphi = \pi$ )

Objective: Stabilize cart-pendulum system to upwards position using MPC in different test scenarios.

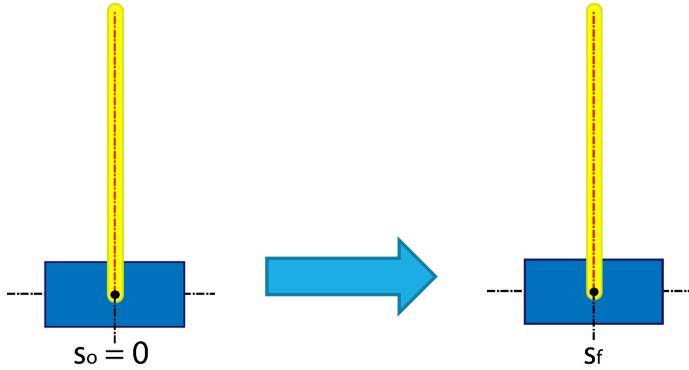
# Test scenarios

---

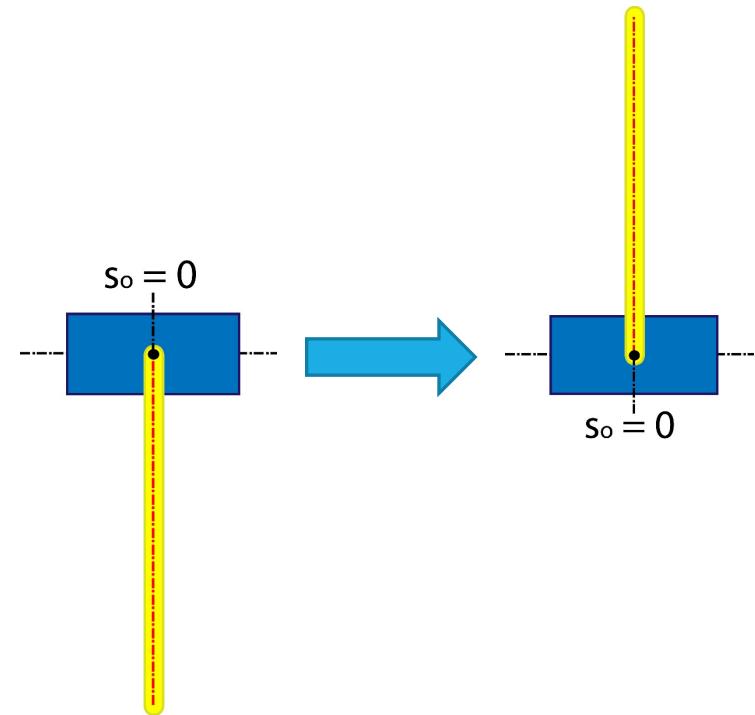
**Stabilization from initial angle**



**Cart movement while keeping pendulum upwards**

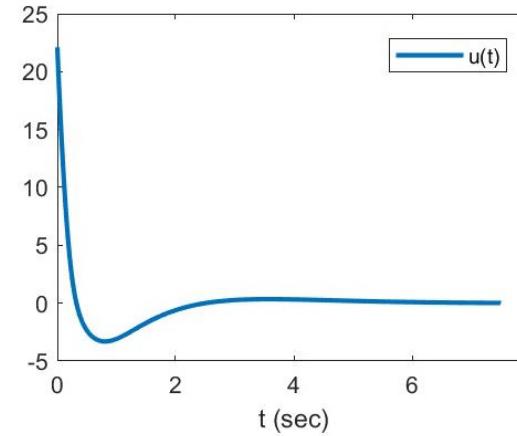
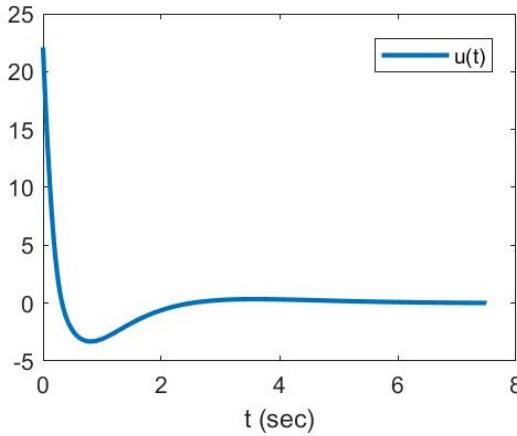
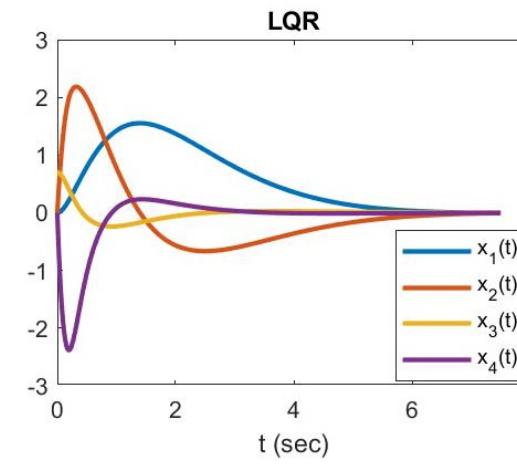
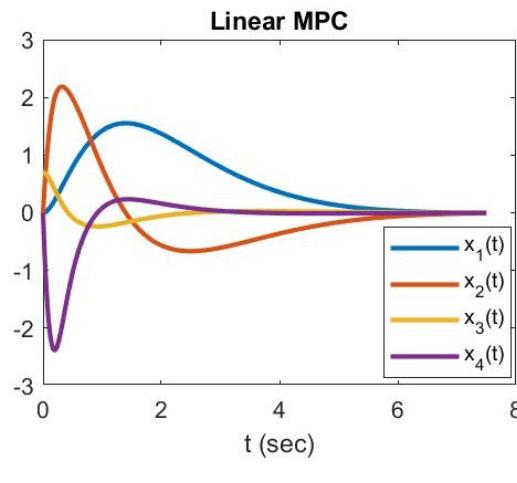


**Wind-up maneuver**



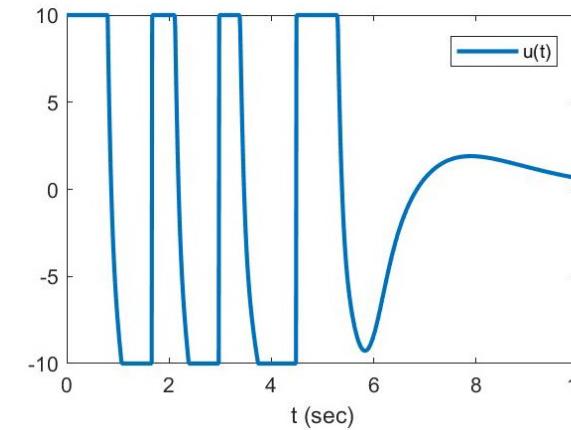
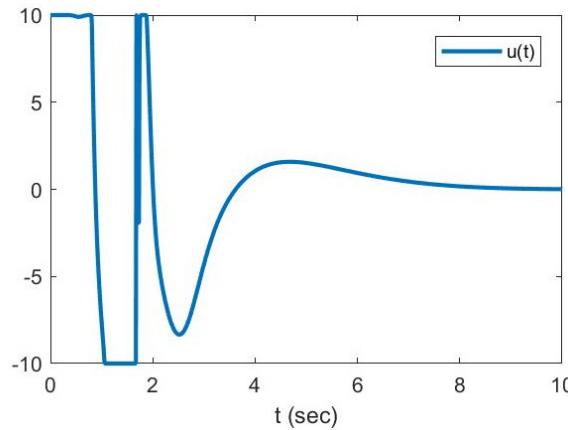
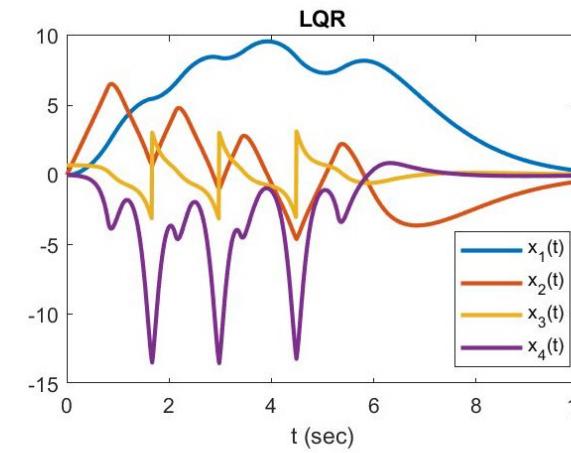
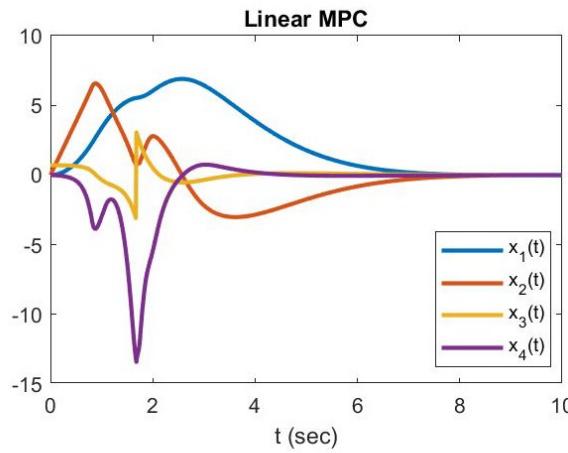
# Stabilization from initial angle (Unconstrained, $\phi_o = 0.7 \text{ rad}$ )

---



# Stabilization from initial angle (Constrained $|u| < 15 N$ , $\phi_0 = 0.7 rad$ )

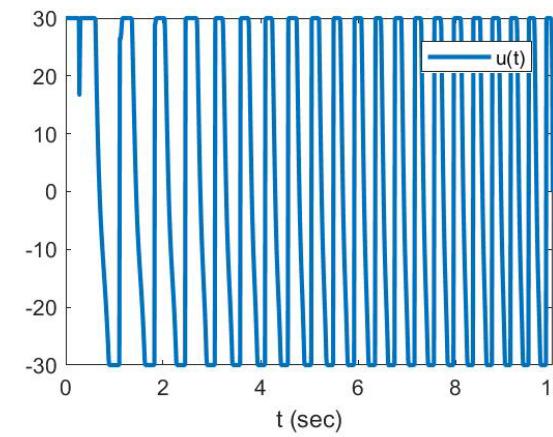
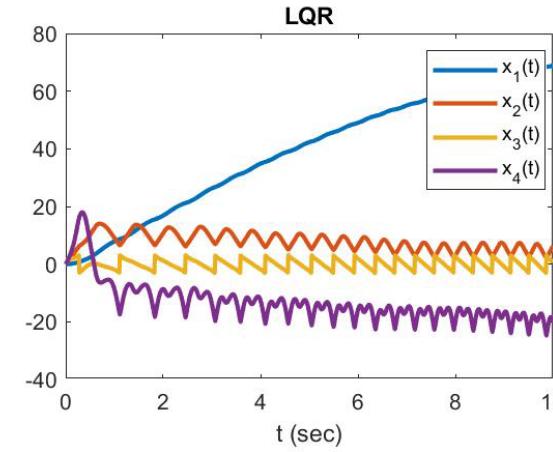
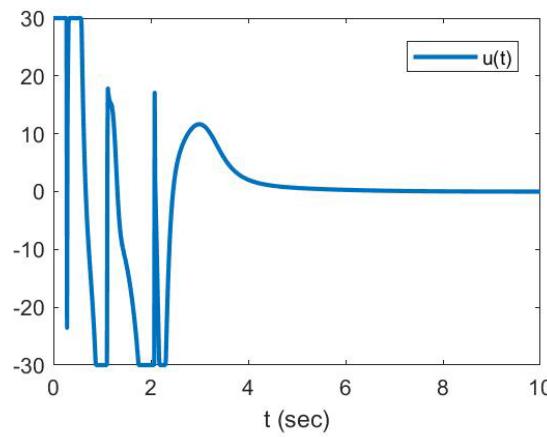
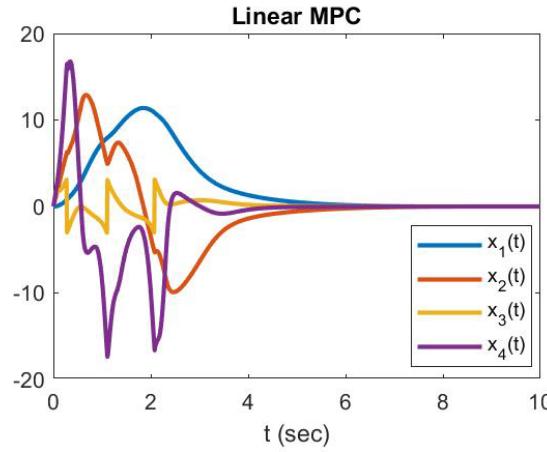
---



# Stabilization from initial angle

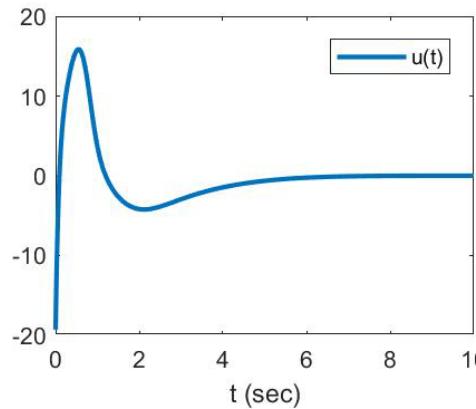
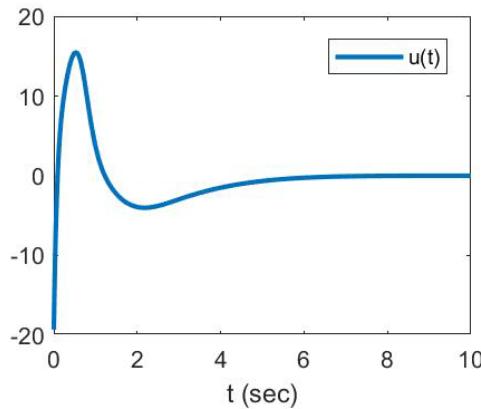
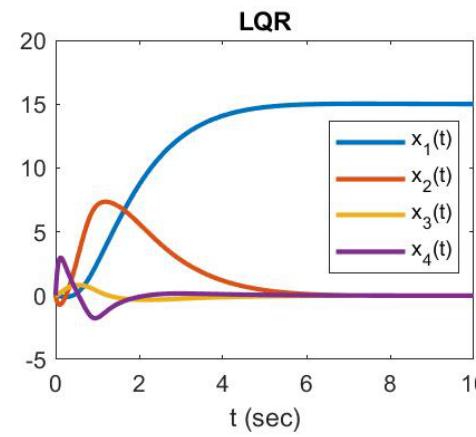
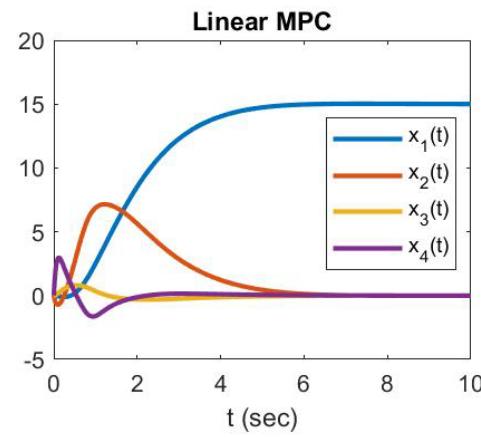
(Constrained  $|u| < 30 \text{ N}$ ,  $\phi_0 = \frac{\pi}{2} \text{ rad}$ )

---



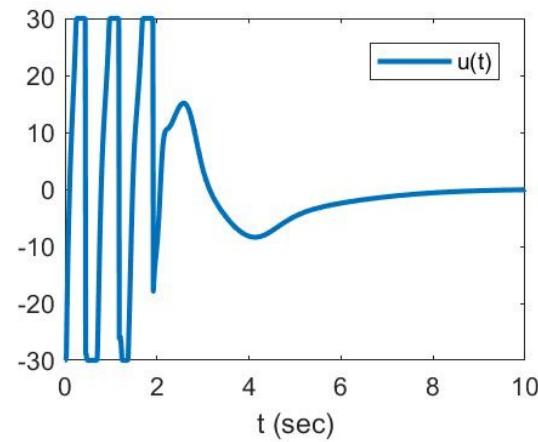
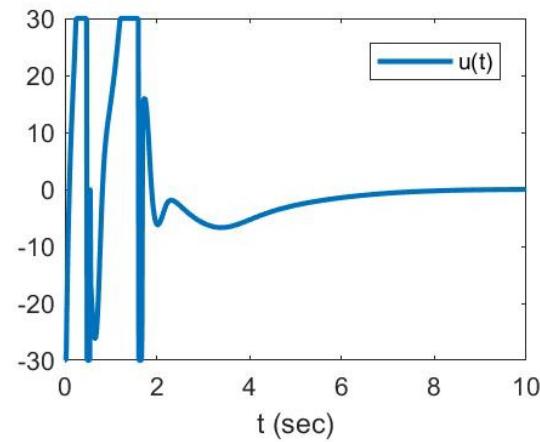
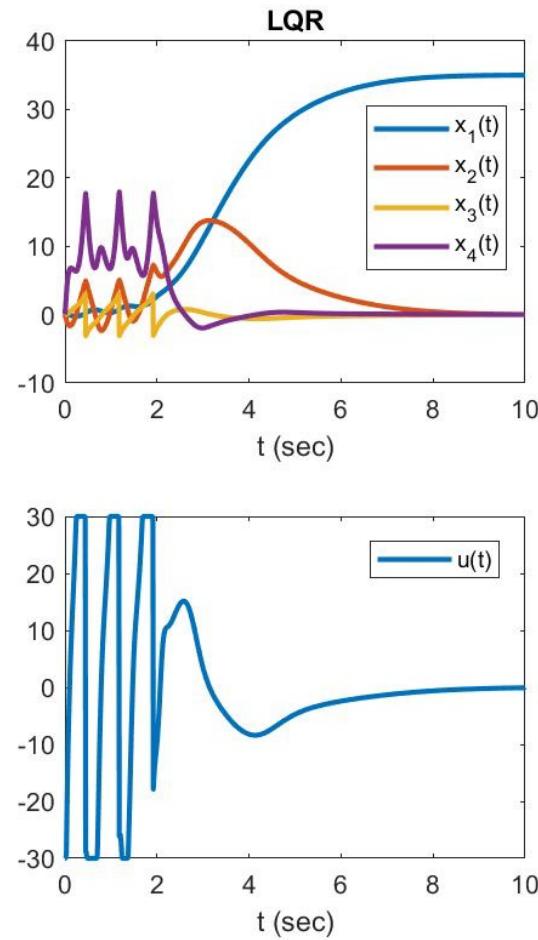
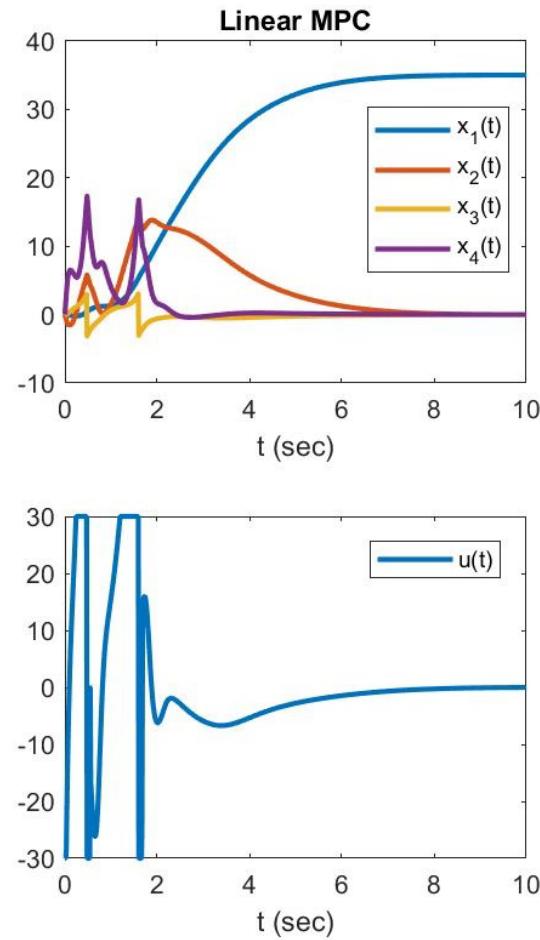
# Cart movement while keeping pendulum upwards (Unconstrained, $s_f = 15 \text{ m}$ )

---



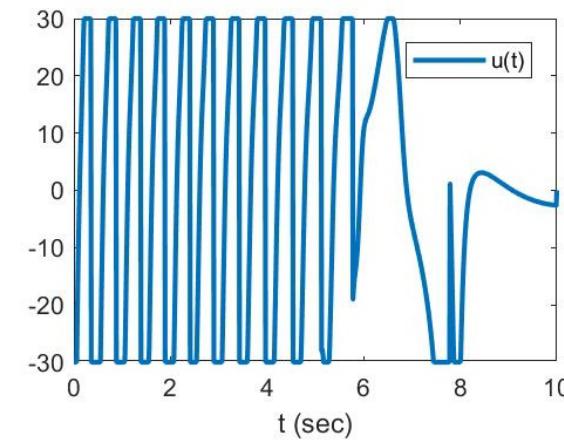
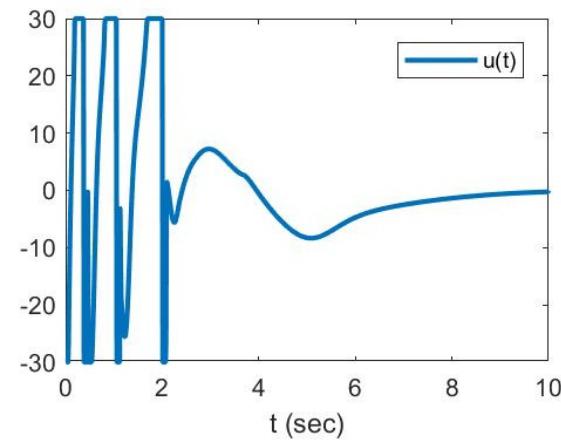
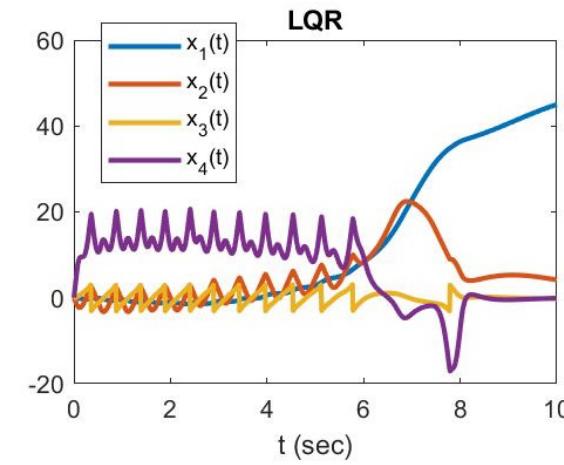
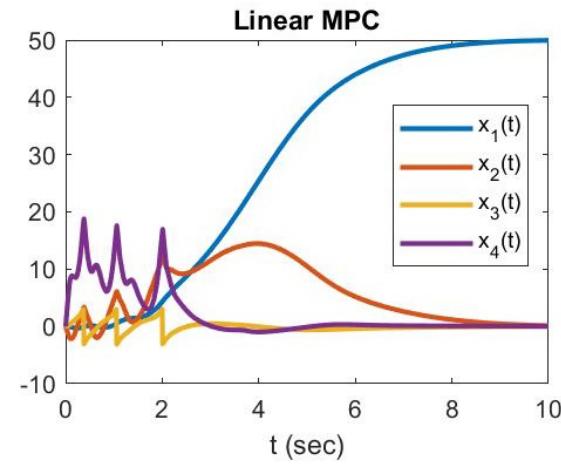
Cart movement while keeping pendulum upwards  
(Constrained  $|u| < 30 \text{ N}$ ,  $s_f = 35 \text{ m}$ )

---



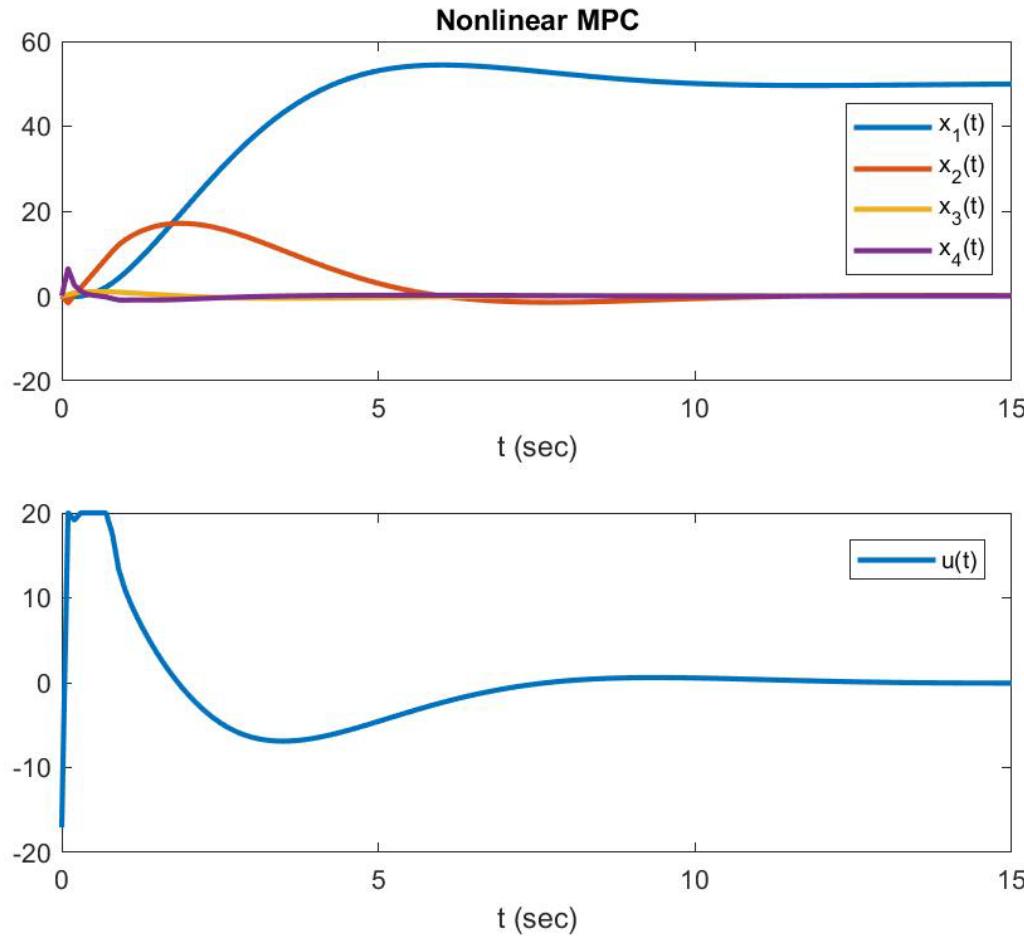
Cart movement while keeping pendulum upwards  
(Constrained  $|u| < 30 N$ ,  $s_f = 50 m$ )

---



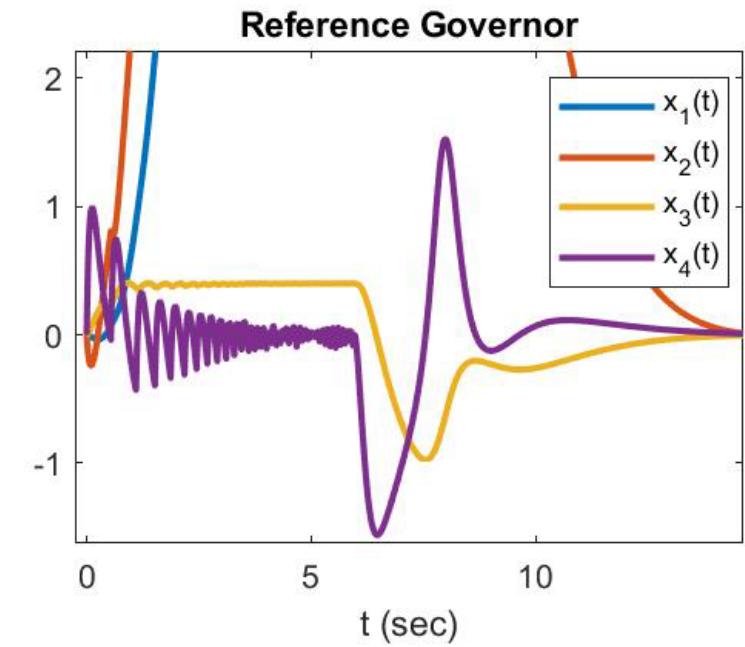
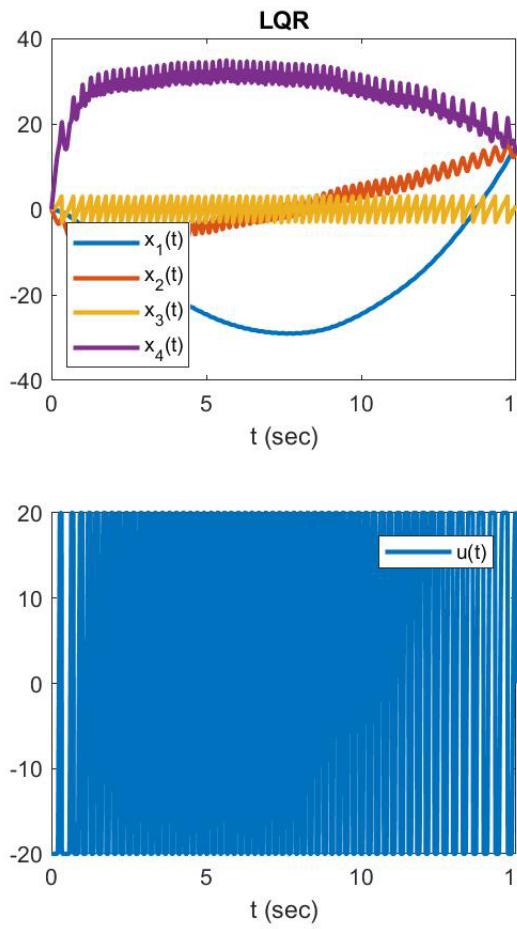
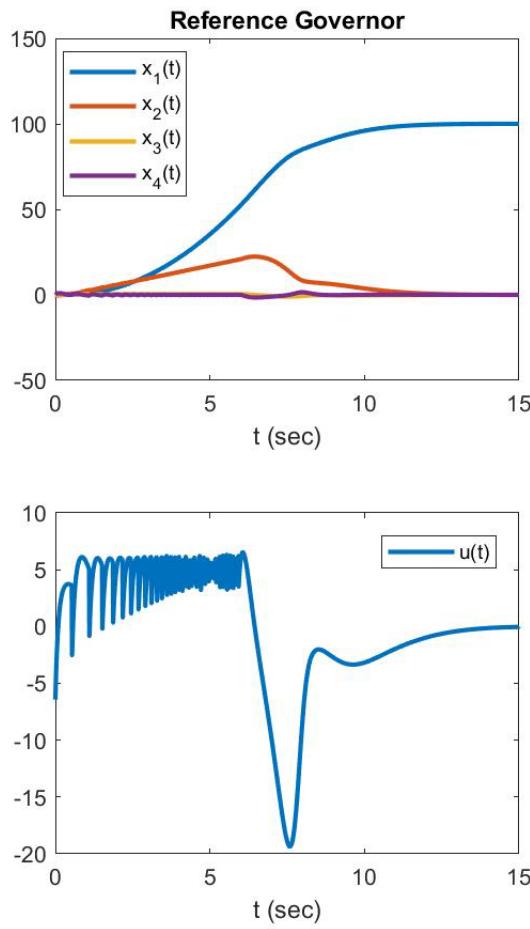
Cart movement while keeping pendulum upwards  
(Constrained  $|u| < 20 \text{ N}$ ,  $s_f = 50 \text{ m}$ )

---



Cart movement while keeping pendulum upwards  
(Constrained  $|u| < 20 \text{ N}$ ,  $s_f = 100 \text{ m}$ )

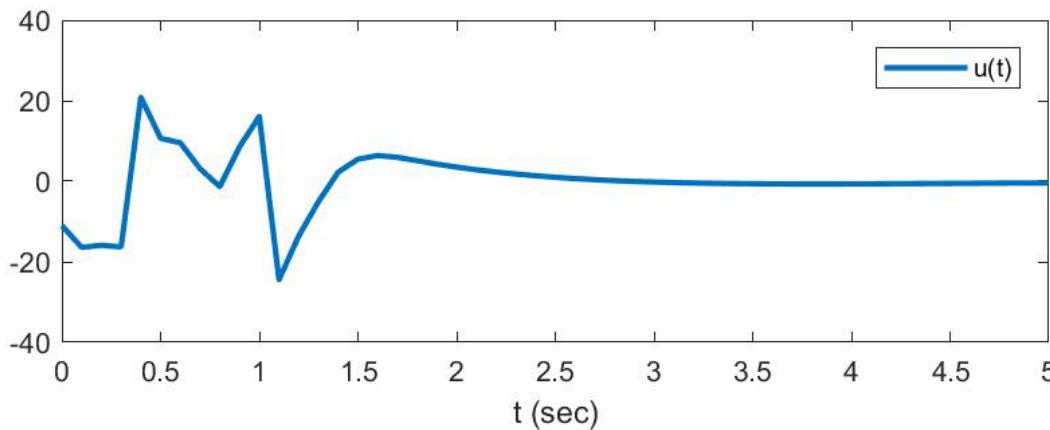
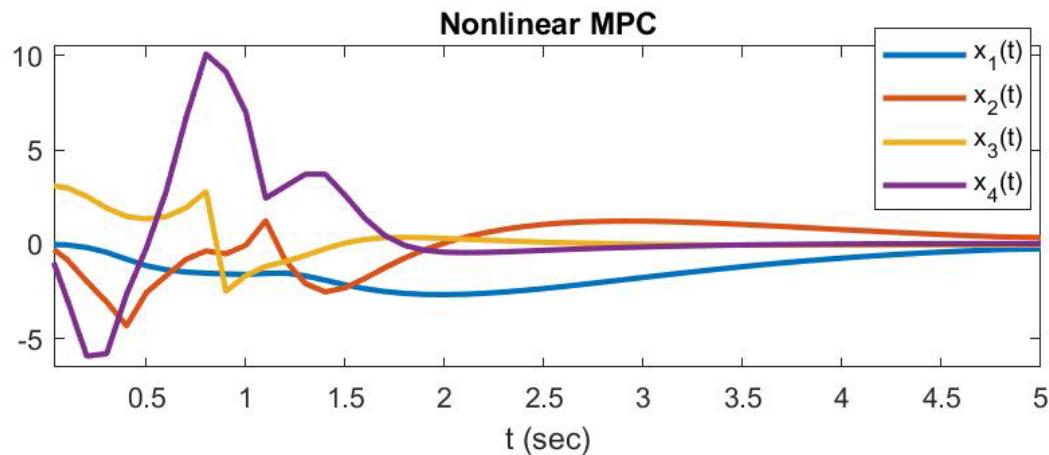
---



# Wind-up Maneuver

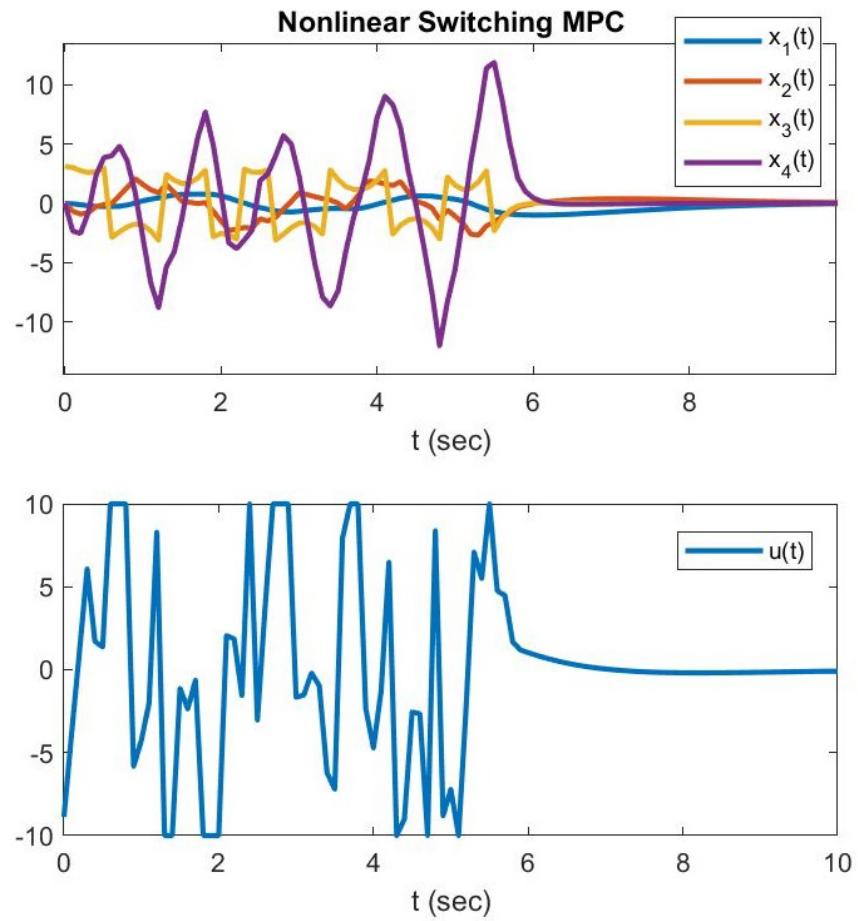
( $|u| < 30 \text{ N}$ ,  $|s| < 2.5 \text{ m}$ )

---



# Wind-up Maneuver

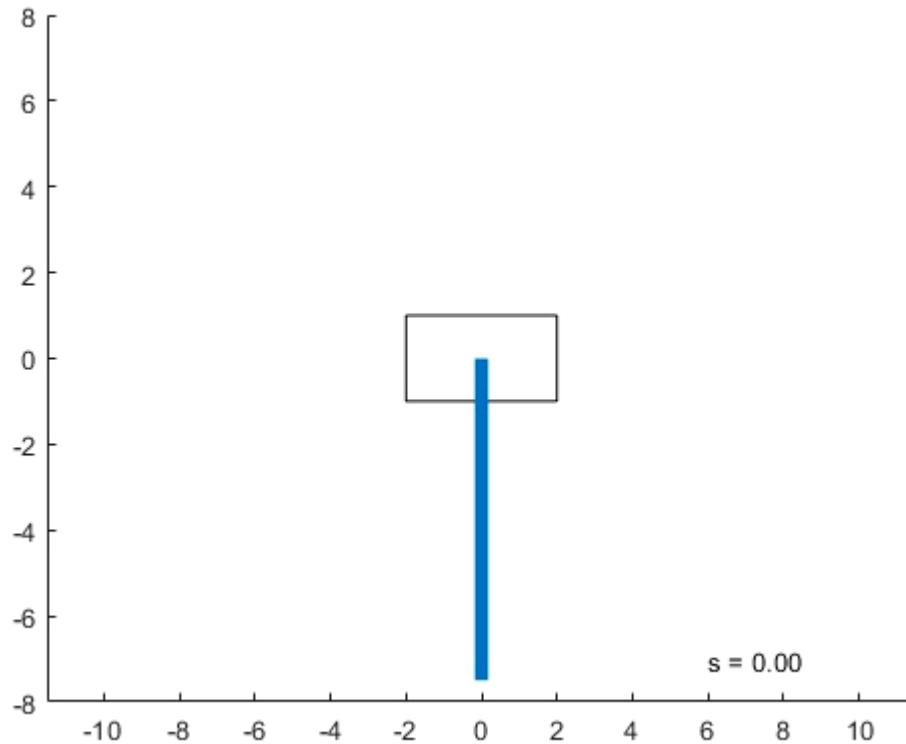
( $|u| < 10 \text{ N}$ ,  $|s| < 1 \text{ m}$  (both violate this one))



# Wind-up Maneuver

( $|u| < 10 \text{ } N$ ,  $|s| < 1 \text{ } m$ )

---



windup\_Switching\_MPC.avi