2025-11-01

E017: Memory Management and Performance

DIP-SMC-PSO Educational Series

January 25, 2026

Overview

This episode covers memory management and performance from the DIP-SMC-PSO project.

Part: Part3 Advanced
Duration: 15-20 minutes
Source: Comprehensive Presentation Materials

section0 HIL Architecture Overview

Network-Based Plant-Controller Separation:

[Visual diagram - see PDF]

Key Benefits:

- **Hardware testing:** Replace plant server with real robot interface - **Network simulation:** Test latency, packet loss effects - **Safety validation:** Emergency stop mechanisms - **Controller portability:** Same controller code for sim/hardware

section0 HIL Safety Mechanisms

Multi-Layer Safety Architecture:

- **Physical Limit Checks**

- Cart position: $|x| < 2.0$ m - Pole angles: $|\theta_1|, |\theta_2| < \pi/2$ rad - Control force: $|u| < 100$ N

- **Timeout Detection**

- Maximum control latency: 100 ms - Heartbeat monitoring (1 Hz) - Automatic emergency stop on timeout

- **Watchdog Timers**

- Control loop must respond within deadline - Watchdog reset every successful cycle - Trigger emergency stop after 3 missed deadlines

- **Manual Override**

- Emergency stop button (keyboard interrupt) - Graceful shutdown sequence - State logging before termination

section0 HIL Latency Monitoring

Real-Time Performance Tracking:

Monitored Metrics:

- **Round-trip time (RTT):** Total communication delay - **Controller computation time:** Time to compute control law - **Network jitter:** Variance in communication delay - **Deadline misses:** Cycles exceeding 100 ms deadline

	Metric	**Value**
	Mean RTT	2-5 ms
Typical Performance (Local Network):	Max RTT	8-12 ms
	Controller compute time	0.5-1 ms
	Deadline miss rate	¡0.1

Allows occasional deadline misses (1

section0 HIL Validation Results

Test Scenarios:

- **Local Simulation (Baseline)**

- Both plant and controller on same machine - RTT: 1-3 ms, zero packet loss - Result: Identical performance to non-HIL mode

- **Network Latency Injection**

- Added 10 ms, 50 ms, 100 ms delays - Controller adapts to latency (predictive compensation) - Result: Stable up to 100 ms, degraded performance beyond

- **Packet Loss Simulation**

- 1 - Timeout recovery and state estimation - Result: Stable up to 5

- **Safety Limit Triggering**

- Deliberately exceeded position/angle limits - Emergency stop activated within 1 time step - Result: No damage, graceful shutdown logged

Resources

- **Repository:** `https://github.com/theSadeQ/dip-smc-pso.git`
- **Documentation:** See `docs/` directory
- **Getting Started:** `docs/guides/getting-started.md`

Educational podcast episode generated from comprehensive presentation materials