A Three-Layer Educational Control Architecture: Samizo-Lab AITL Controller (A-type)

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***Abstract*—This paper presents a modular and interpretable educational control architecture referred to as the AITL Controller (A-type). The framework consists of three layers: a PID inner loop for baseline stabilization, an FSM supervisory layer governing mode-dependent behavior, and a lightweight LLM-based adaptive mechanism adjusting the proportional gain under large-error conditions. The architecture clearly separates the roles of stability control, supervisory logic, and adaptive response. This framework is intended as an educational and architectural demonstration, not as a safety-certified or robustness-guaranteed control system.**

***Index Terms*—PID control, supervisory control, FSM, adaptive systems, educational control architecture**

I. Introduction

Multi-layer control architectures are widely used in practical systems to handle disturbances, nonlinearities, and mode-dependent behavior [1]. Classical PID control is well understood [2], yet educational frameworks often lack clear separation of control-layer roles.

Deterministic finite-state machines (FSMs) provide a structured approach for supervisory switching [3]. Recent progress in AI-assisted control motivates hybrid schemes that include lightweight adaptive elements [4].

The Samizo-Lab AITL Controller (A-type) integrates: (1) a PID baseline stabilization loop, (2) an FSM supervisory switching layer, and (3) an LLM-driven adaptive gain mechanism.

II. AITL Architecture

A. Three-layer Structure

Figure 1 shows the overall structure of the AITL Controller. Each layer plays a distinct role, enabling a clear separation of stabilization, supervisory logic, and adaptive behavior.

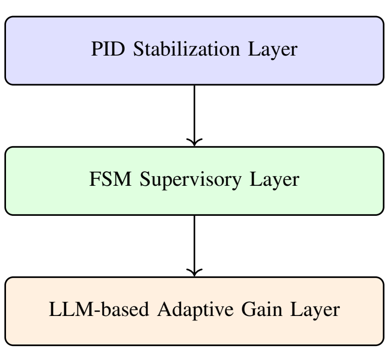

Fig. 1. Three-layer AITL Controller architecture.

B. FSM Supervisory Logic

The FSM switches modes according to:

$$|e(t)| > \theta_{\text{high}} \Rightarrow \text{high-response mode.} \tag{1}$$

Figure 2 illustrates the supervisory state transitions.

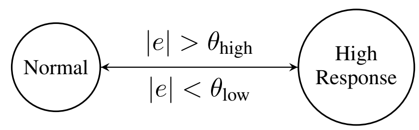

Fig. 2. FSM transitions of the AITL Controller.

C. LLM-Based Adaptive Layer

The LLM adjusts the proportional gain k_p only in the high-response mode, improving transient and disturbance response. The LLM does not operate in the real-time control loop and does not perform continuous optimization. It selects predefined gain values under the supervision of the FSM.

III. Simulation Results

A step input was applied at $t = 0\,\text{s}$, and disturbances at $t = 5\,\text{s}$ and $t = 15\,\text{s}$.

The PID loop ensures stability, the FSM switches modes appropriately, and the LLM enhances transient performance.

IV. Conclusion

The AITL Controller (A-type) provides a clear and modular educational framework combining PID regulation, FSM supervision, and LLM-based adaptive gain tuning. Its structural transparency supports intuitive learning of multi-layer control. Future work includes reliability-oriented supervisory architectures and operational robustness frameworks built upon this baseline.

References

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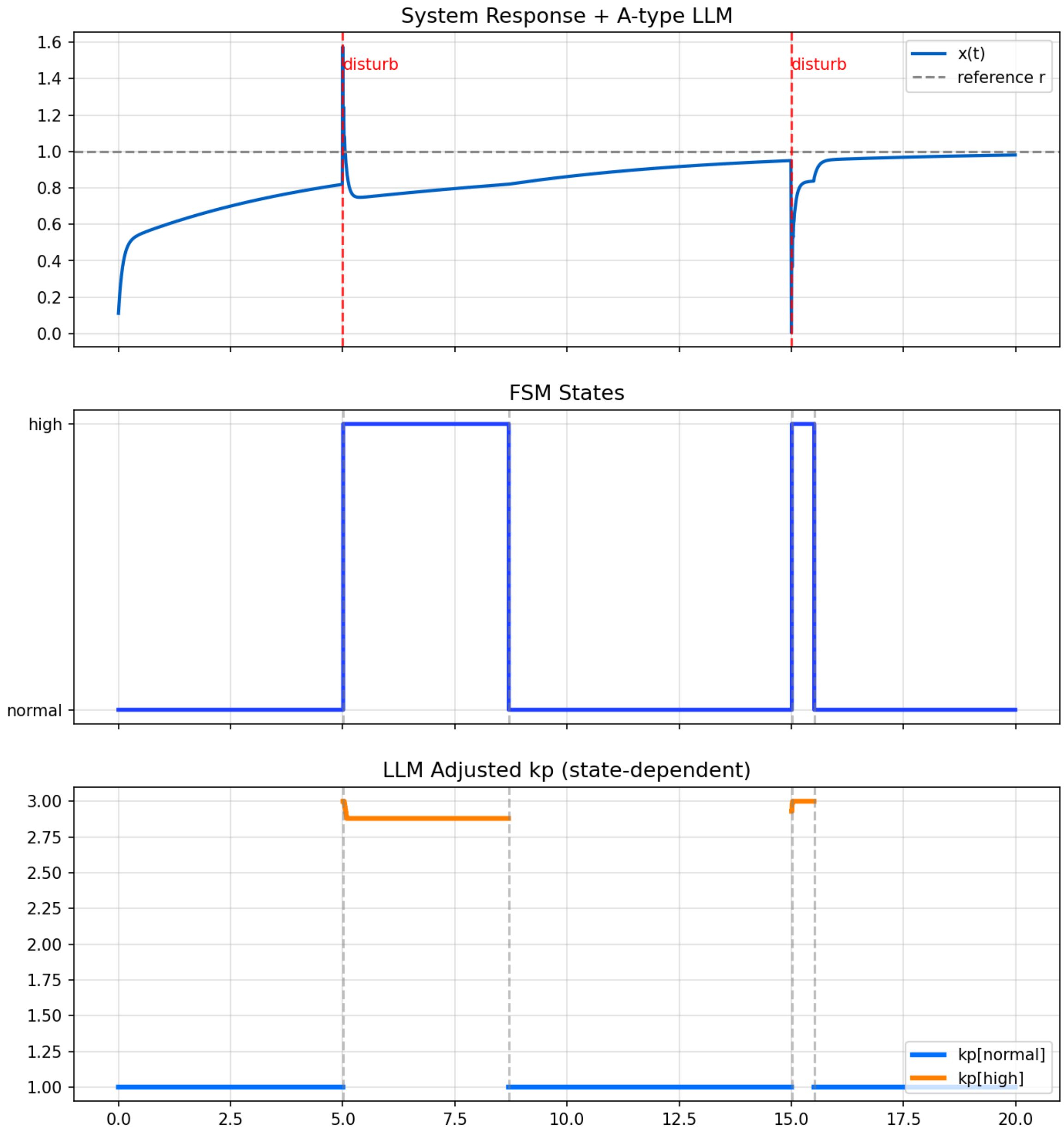

Fig. 3. System response, FSM transitions, and LLM-adjusted proportional gain under disturbance conditions.

Author Biography

Shinichi Samizo received the M.S. degree in Electrical and Electronic Engineering from Shinshu University, Japan. He worked at Seiko Epson Corporation in semiconductor memory and mixed-signal development, contributing to inkjet MEMS actuators and PrecisionCore printhead technology. He is currently an independent researcher focusing on semiconductor education, memory architecture, and AI-assisted control systems.

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https://github.com/Samizo-AITL