IOCMA 2026 Conference
The 2nd International Online Conference on Mathematics and Applications
10–12 June 2026 | Online
MDPI

A Hybrid Pole-Placement and Deadbeat Controller for Discrete-Time Systems

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INTRODUCTION

Deadbeat controllers achieve finite-time convergence in discrete-time linear systems by driving all state variables to the origin within exactly n steps, where n denotes the system order. Despite this theoretical optimality, pure deadbeat control suffers from prohibitively large initial control magnitudes, which frequently induce actuator saturation and render the controller impractical for physical implementation. This fundamental trade-off between convergence speed and control feasibility constitutes a critical open challenge in digital control design.

METHOD

This paper proposes a two-phase hybrid control architecture that rigorously reconciles finite-time convergence with actuator constraints. During Phase I (1 to m), an Ackermann pole-placement law repositions the closed-loop eigenvalues to prescribed locations within the open unit disk, moderating transient control amplitudes while ensuring asymptotic state reduction. At step $m+1$, Phase II activates a standard deadbeat formulation that eliminates the residual error in exactly n additional steps. A unified state-space formulation is derived, and Lyapunov-based stability arguments confirm that the switching does not introduce instability. The total convergence time is analytically determined to be $T_c = m + n$ steps.

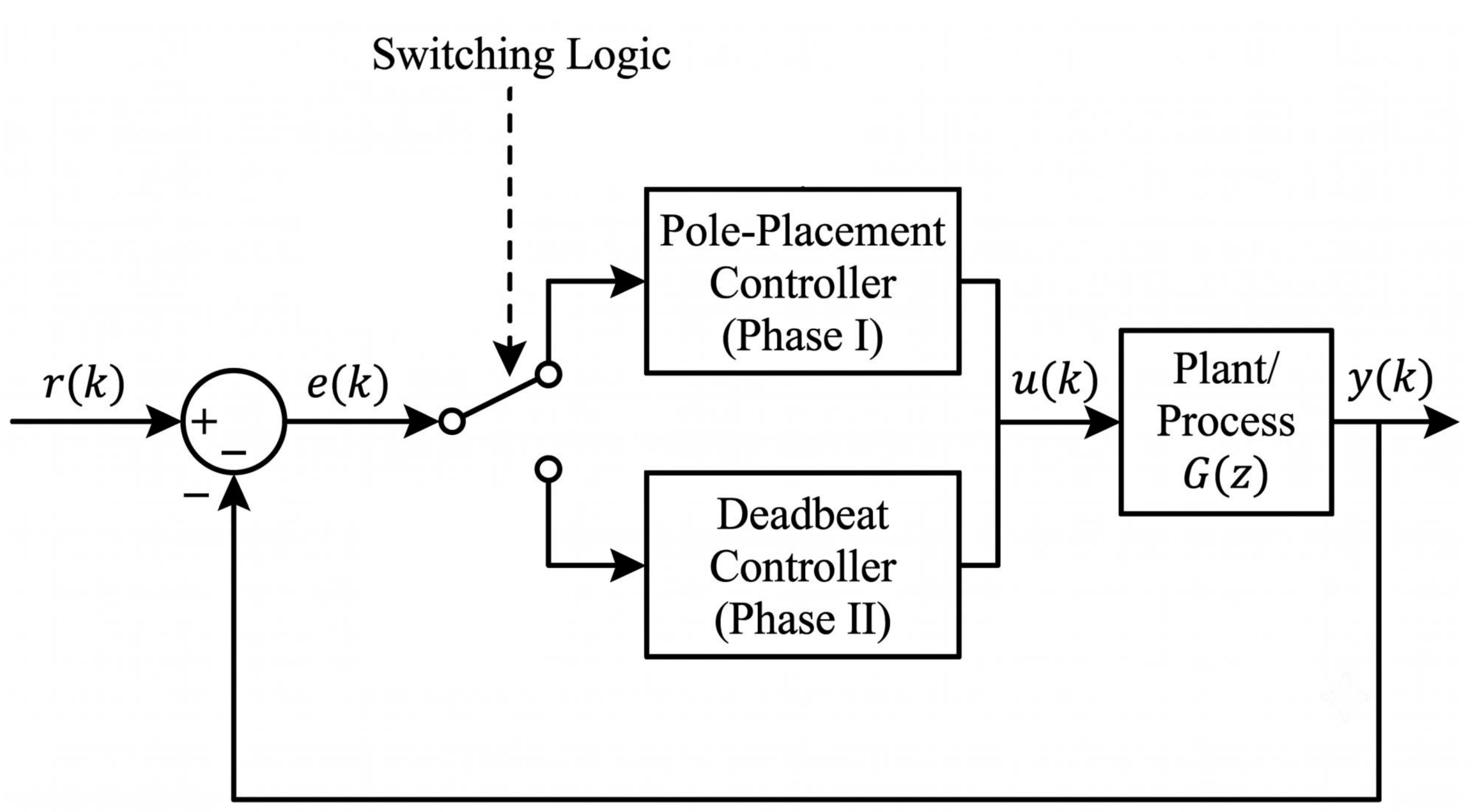

Figure 1: The proposed control block diagram.

RESULTS

Comparative simulations on a second-order discrete-time plant $(n = 2)$ demonstrate that the hybrid scheme significantly reduces peak control effort. Specifically, the peak effort drops from 9.50 in pure deadbeat to 3.80 and 3.72 for hybrid modes $m = 2$ and $m = 4$, respectively, achieving up to a 61% reduction. Meanwhile, the Mean Square Error (MSE) shifts from 4.13 (pure deadbeat) to 5.58 $(m = 2)$ and 5.45 $(m = 4)$. This confirms that increasing the switching instant m effectively reduces peak control magnitude at the cost of a proportional increase in settling time and transient error.

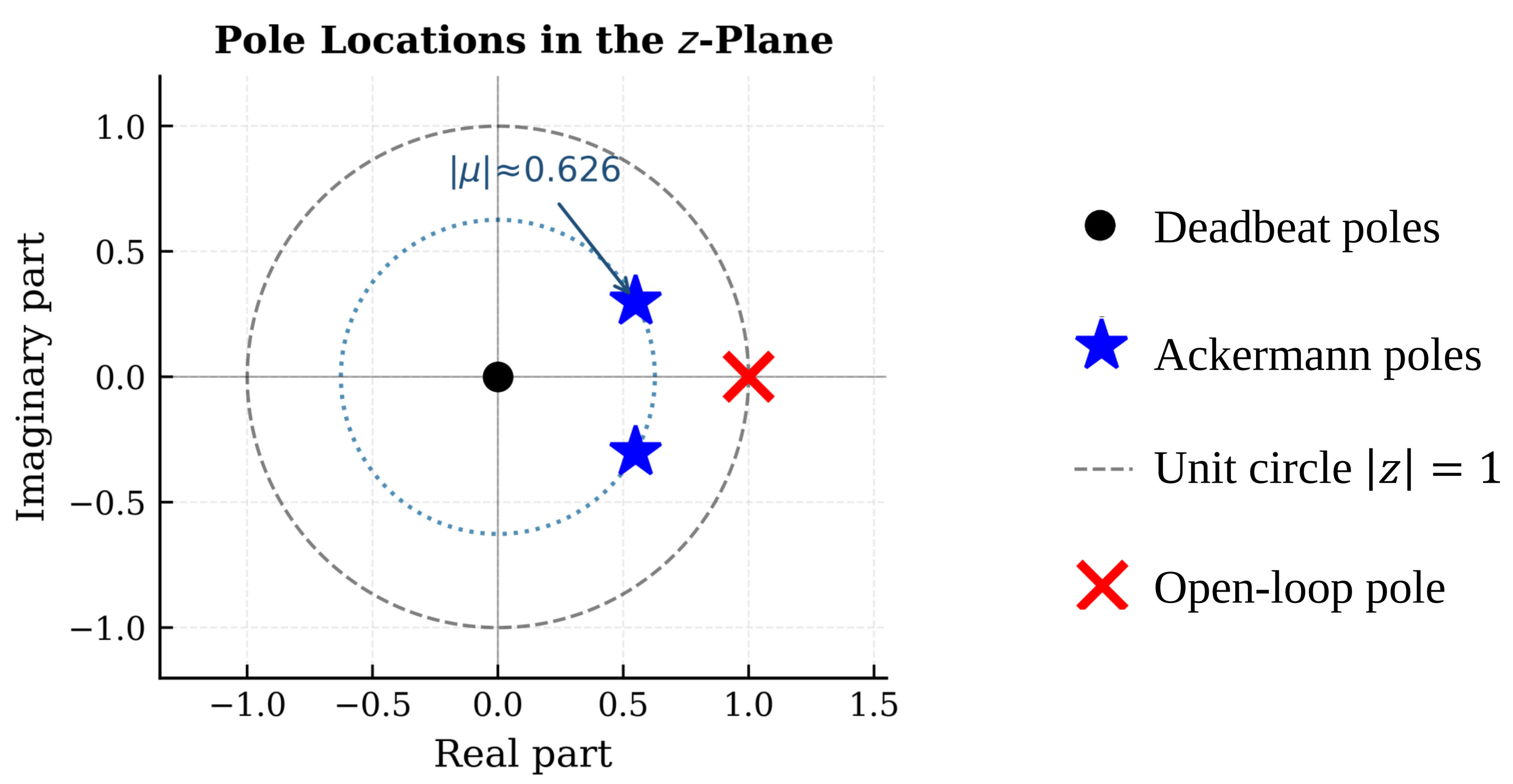

Figure 2: The pole locations in the z-plane.

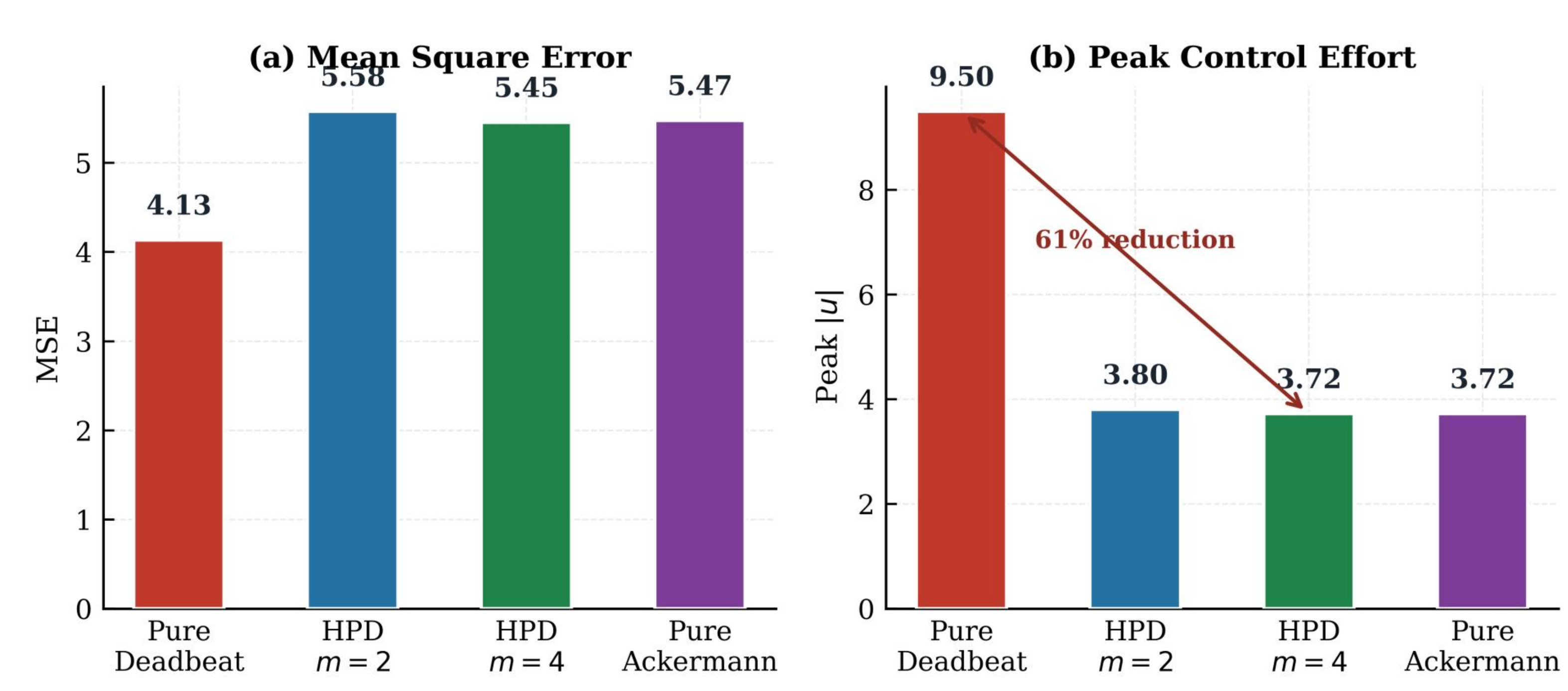

Figure 3: This chart demonstrates that the use of the proposed method significantly reduces the peak control effort, thereby enabling its practical application for actuators in real-world scenarios.

CONCLUSION

The proposed m-step Ackermann / $(m + 1)$-deadbeat hybrid controller provides a formally grounded, tunable framework for discrete-time control design. By parameterizing the switching instant m, practitioners can explicitly trade off convergence speed for reduced control effort, enabling actuator-aware implementation without sacrificing the zero-steady-state-error guarantee of deadbeat control.

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