“I Got the Moves Like Robot”: A Comparative Analysis of Dynamic Movement Primitives and Classical Kinematic Trajectories

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When a robot’s target goal is dynamically shifted mid-flight, how do Dynamic Movement Primitives compare to classical polynomial trajectories in terms of joint velocity smoothness and mathematical adaptability?

1 Introduction

Objective: Compare two robotics applications under realistic and sudden movement constraints to address the core research question.
Methodology: Conduct comparative analyses using high-frequency numerical simulation sandboxes.
Evaluation: Map resulting trajectory profiles against the constraints of 5-DOF and 7-DOF manipulator architectures.

2 Architecture & Frameworks

Classical Quintic Polynomial Framework: Goverened by fifth-order polynomials and matrix algebra calculations.

$$y(t) = c_0 + c_1 t + c_2 t^2 + c_3 t^3 + c_4 t^4 + c_5 t^5$$

Dynamic Movement Primitive Framework: Governed by second-order differential equations through a mass-spring damper system and an attractor variable which updates with movement.

$$\tau \dot{z} = \alpha_z(\beta_z(g - y) - z) + f(x)$$

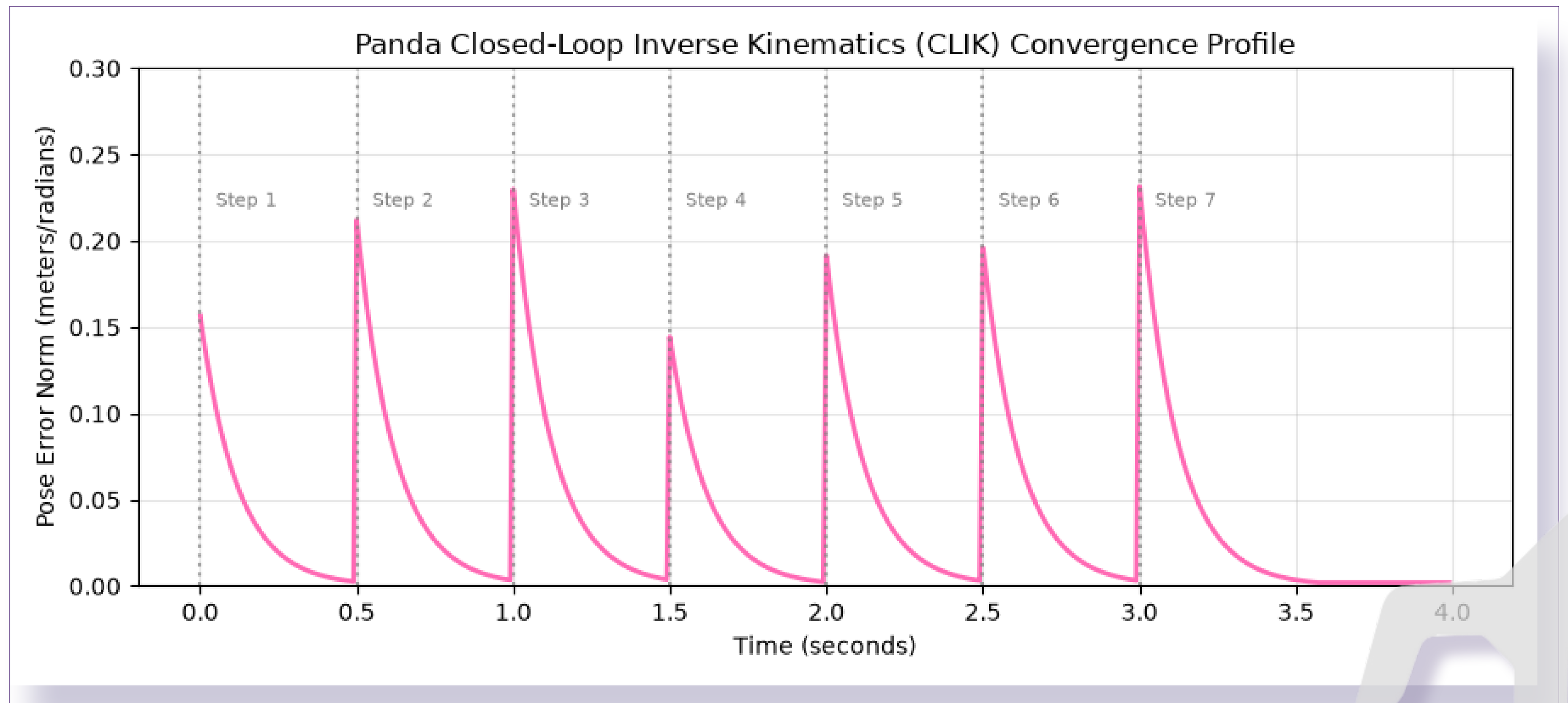
3 Methodology

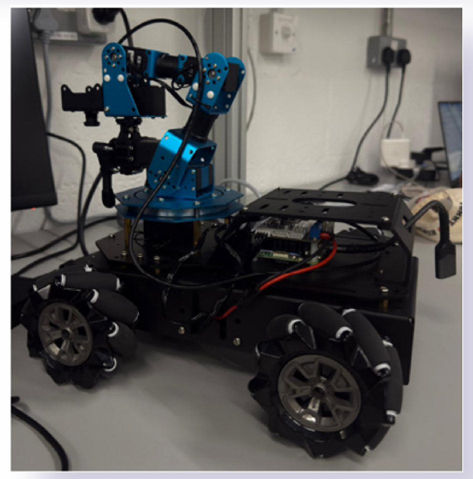
Phase 1: Physical Hardware Motivation & Constraints:

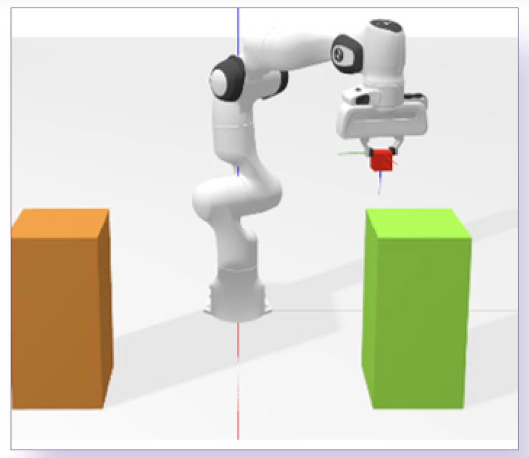
Phase 2: Standalone Python Mathematical Sandbox

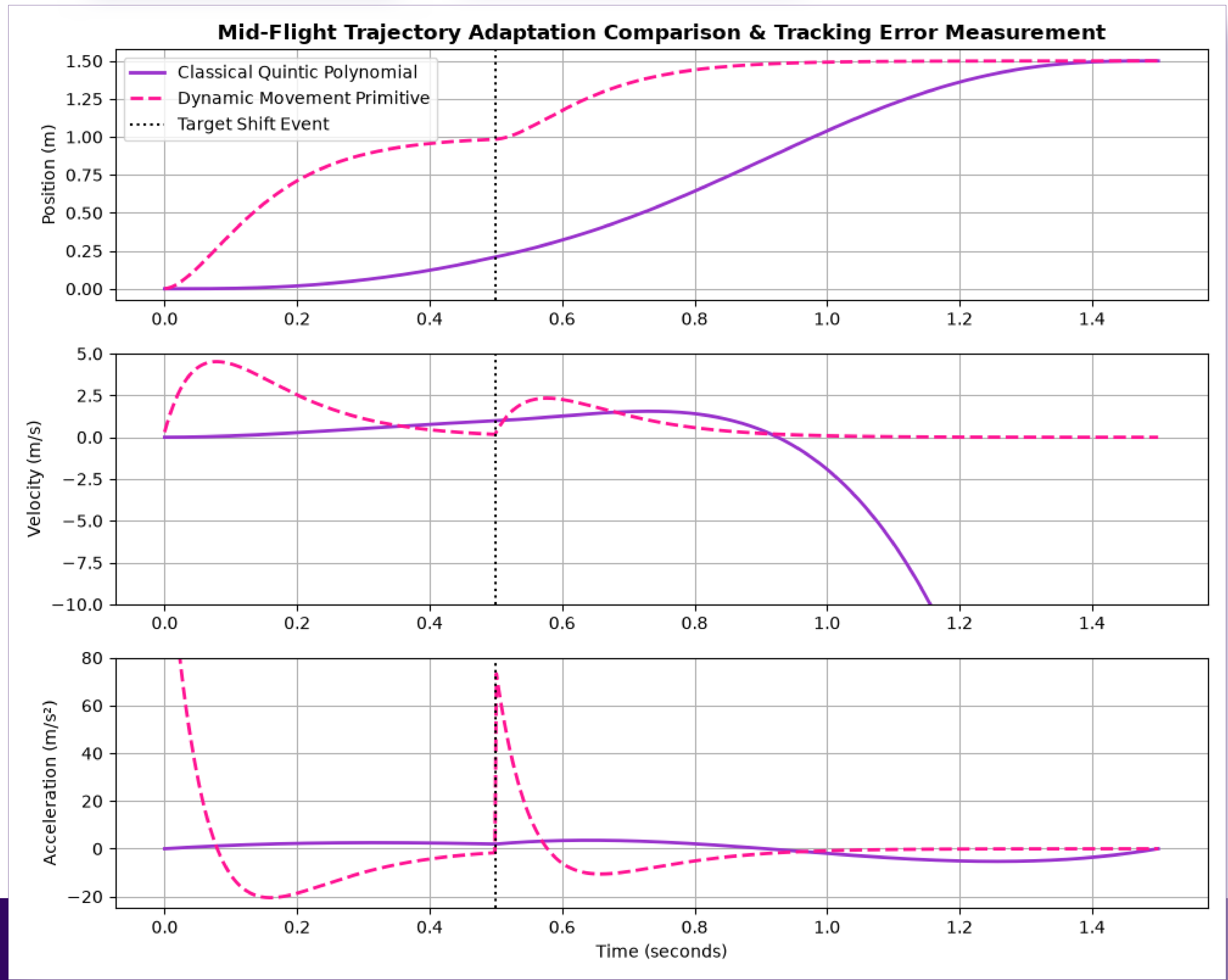
Phase 3: Experimental Stress Testing (750 Timesteps)

Phase 4: Comparative Results & Feasibility Analysis









Results & Discussion 4

Baseline Performance: The Franka Panda CLIK system validates baseline static tracking, showing error decay to zero across all operational states.
Polynomial Failure: Mid-flight target shifts induce boundary crises in quintic replanning, causing velocity spikes that exceed hardware limits.
DMP Attractor Absorption: Canonical spring-damper dynamics absorb perturbations seamlessly through critically damped, transient acceleration spikes.
Deployment Feasibility: DMP guarantees bounded spatial velocities, ensuring downstream hardware safety in dynamic settings.
Key Takeaway: DMPs are the mathematically superior paradigm when a robot’s target goal is dramatically shifted mid-flight.

5 Key Citations

[1] Matteo Saveriano, Fares J. Abu-Dakka, Aljaz Kramberger, & Luka Peternel (2021). Dynamic Movement Primitives in Robotics: A Tutorial Survey. CoRR, abs/2102.03861.
[2] R. S. Sharma, S. Shukla, H. Karki, A. Shukla, L. Behera and V. K.S., “DMP Based Trajectory Tracking for a Nonholonomic Mobile Robot With Automatic Goal Adaptation and Obstacle Avoidance,” 2019 International Conference on Robotics and Automation (ICRA), Montreal, QC, Canada, 2019, pp. 8613-8619, doi: 10.1109/ICRA.2019.8793911.
[3] Ijspeert, A.J. & Nakanishi, Jun & Hoffmann, Heiko & Pastor, Peter & Schaal, Stefan. (2013). Dynamical Movement Primitives: Learning Attractor Models

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