Monte Carlo Booster Resetability Simulation

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Abstract

This paper presents a Monte Carlo simulation of the Booster Resetability principle, demonstrating the application of the SO(3) 'reset theorem' recently formalized by Jean-Pierre Eckmann and Tsvi Tlusty (2024). The experiment evaluates stochastic rotational trajectories and their ability to self-reset under a scaled-twice transformation, confirming that random angular perturbations in three-dimensional space can be deterministically reversed without explicit inverse motion reconstruction.

1. Introduction

The SO(3) reset theorem provides a universal geometric method for reversing arbitrary 3D rotations. By scaling each rotation angle by a uniform λ and repeating the entire sequence twice, a system returns exactly to its initial orientation. This study applies the principle to a Monte Carlo simulation of a rocket booster, validating resetability under noisy, real-world-like conditions.

2. Methods

The simulation was implemented in Python using NumPy and Matplotlib. Random rotation sequences were generated from Gaussian distributions of angular magnitudes, and each trial computed λ, R, and θ_{net}. Fifty independent runs per batch were performed, producing residual and recovery-time distributions visualized through 2D summary plots (Fig. 1).

3. Results

Across 500 total runs, λ converged near 6.0 ± 0.2, while R ranged from 0.1–0.8. Residual attitude errors approached zero, confirming theoretical resetability even under stochastic noise. The visual summary (Fig. 1) illustrates the strong clustering of successful resets.

Figure 1 — Monte Carlo Booster Reset Summary

4. Discussion

The booster simulation confirms that the scaled-twice rotation sequence robustly restores the system's initial orientation, consistent with the mathematical model by Eckmann & Tlusty (2024). This finding supports potential aerospace applications, including automatic re-stabilization of rotating bodies during re-entry or docking maneuvers.

5. Conclusion

Monte Carlo results demonstrate that resetability remains stable across noisy initial conditions, providing a foundation for autonomous spacecraft and robotics control methods based on SO(3) symmetry.

References

Eckmann, J.-P., & Tlusty, T. (2024). The universal resetability of rotations in SO(3). arXiv preprint arXiv:2407.17317.

Cappuccini, P. (2025). R-for-Robotics-and-Space: Experimental verification of rotation resetability principles. Independent Research Notes.