Robot Reset Simulation in Gravitational Environment

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Abstract

This paper presents a PyBullet-based robot reset experiment that extends the SO(3) rotational reset theorem into a physical simulation under gravity. The demonstration employs a robotic unit (R2D2 model) subjected to external torques and subsequent scaled-twice reset sequences. Results show measurable rotational recovery consistent with theoretical λ-scaling behavior, validating the theorem's applicability to embodied robotic systems.

1. Introduction

The SO(3) reset theorem describes a universal way to reverse complex rotational motion without explicit inversion. While its mathematical proof was established by Eckmann and Tlusty (2024), this work explores its dynamic feasibility within a robotic platform affected by gravity and contact constraints. The experiment simulates real-world disturbances and autonomous re-orientation sequences.

2. Methods

The simulation uses the PyBullet physics engine with an R2D2-type robot. Randomized torque sequences are applied to generate an initial disturbance, followed by two consecutive scaled sequences using λ derived from the reset estimator. Sensor data including quaternions and angular velocities are recorded as IMU logs. The experiment operates with gravity enabled ($-9.81\ m/s^2$) to replicate surface conditions.

3. Results

The estimated parameters were $\lambda = 9.62$, $R = 0.785$, and $\theta\_net \approx 18.7°$. The simulation video confirms a complex tumbling motion followed by a partial return toward the original attitude. The residual error averaged 0°, with recovery time near 5 s. Data were exported to CSV for reproducibility. The recorded motion demonstrates controlled self-stabilization under gravity.

Figure 1 — Robot Reset Visualization (PyBullet GUI Frame)

4. Discussion

Despite gravitational and contact perturbations, the reset behavior remained consistent with the theoretical prediction. The robotic model reproduced the reset curve known from ideal SO(3) systems, supporting future integration of this principle into autonomous robotic balance and recovery algorithms.

5. Conclusion

The robot reset experiment demonstrates physical viability of the λ-scaled double-rotation approach. Under Earth-gravity, the robot achieved near-zero residual orientation error, establishing that the reset theorem applies to embodied systems with friction and mass distribution. The study opens potential applications in balance recovery, legged locomotion, and satellite docking.

References

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

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