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Unified Multi-Rate Model Predictive Control for a Jet-Powered Humanoid Robot

ISTITUTO ITALIANO DI TECNOLOGIA

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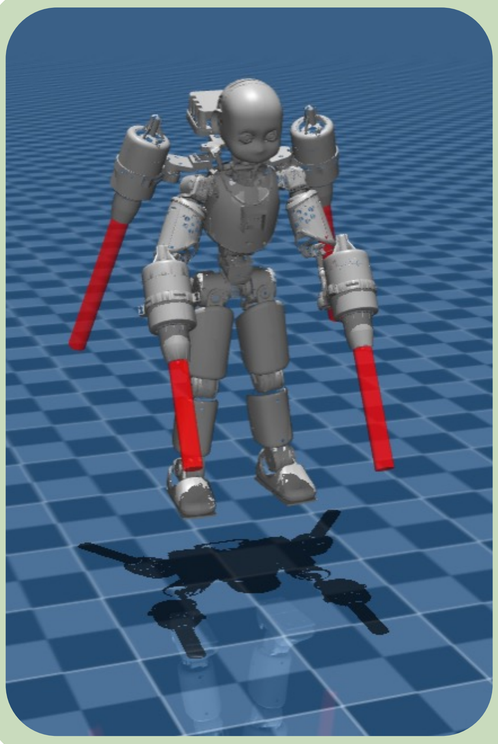


Key Points

Problems:

Flying humanoid robots require controllers that that handles both **fast joints** and **slow jet engines**, but existing approaches either **neglect jet dynamics** or **cannot run online** in real time.

Solution:

We introduce a **unified multi-rate Model Predictive Control** framework that embeds **jet dynamics** directly into a **momentum-based model**, generating control commands at **actuator-specific frequencies**.

Outcome:

Our controller enables robust **disturbance recovery**, smooth **trajectory tracking**, and **real-time execution** at 200 Hz, paving the way toward stable flight in jet-powered humanoids.

Paper

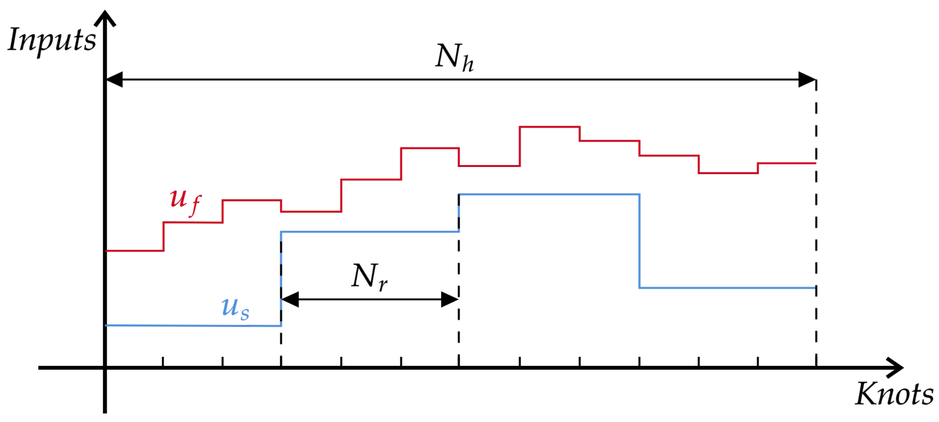
GitHub Code

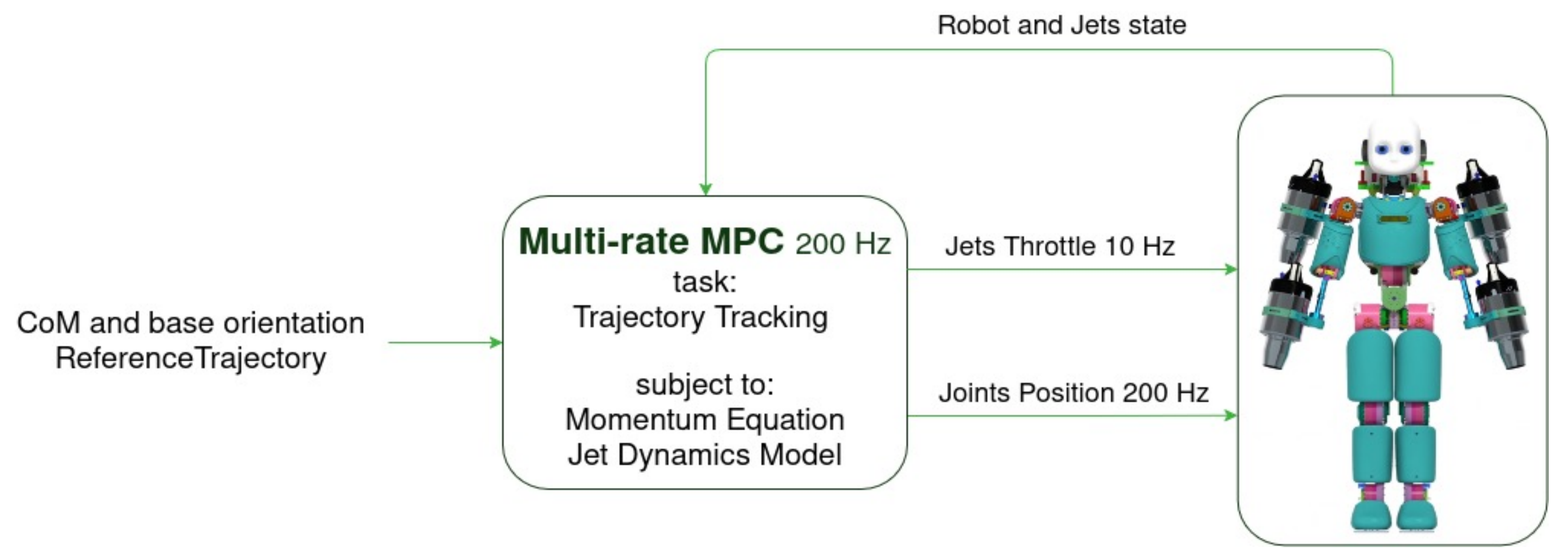
Method overview

Multi-rate MPC:
Generates joint commands at high frequency (200 Hz) and jet commands at low frequency (10 Hz) in a unified predictive framework.

Modeling:
Centroidal momentum + nonlinear jet propulsion model, linearized with LPV approximation.

Implementation:
Runs at 200 Hz using OSQP solver; validated in MuJoCo with iRonCub and turbine dynamics identified from real experiments.





Results

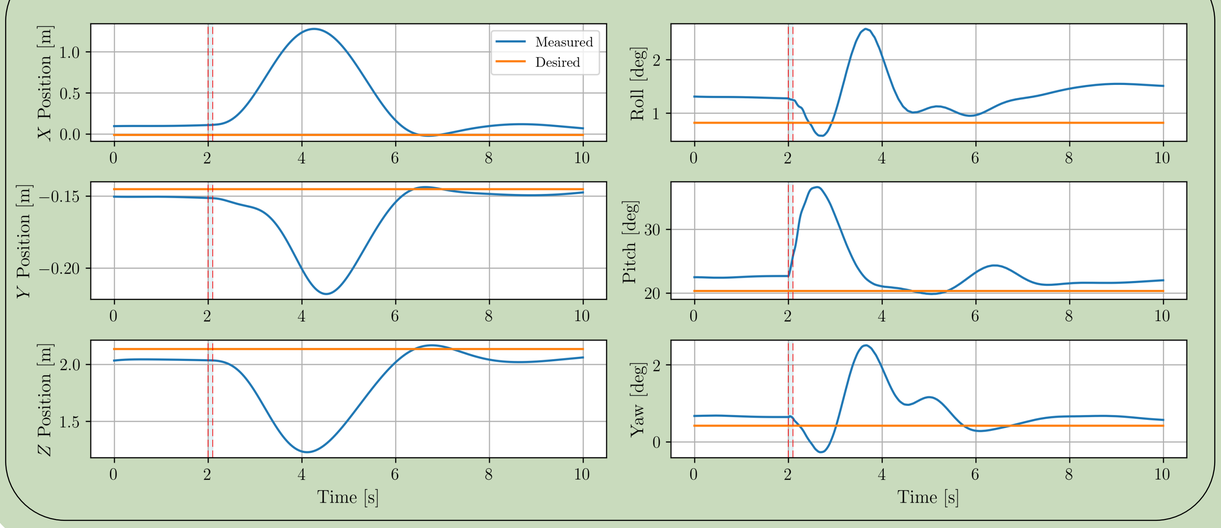
Disturbance Recovery:
Withstands 50 N force and 300 Nm torque.

Trajectory Tracking:
Tracks minimum-jerk trajectory with low errors; multi-rate MPC reduces oscillations vs. single-rate.

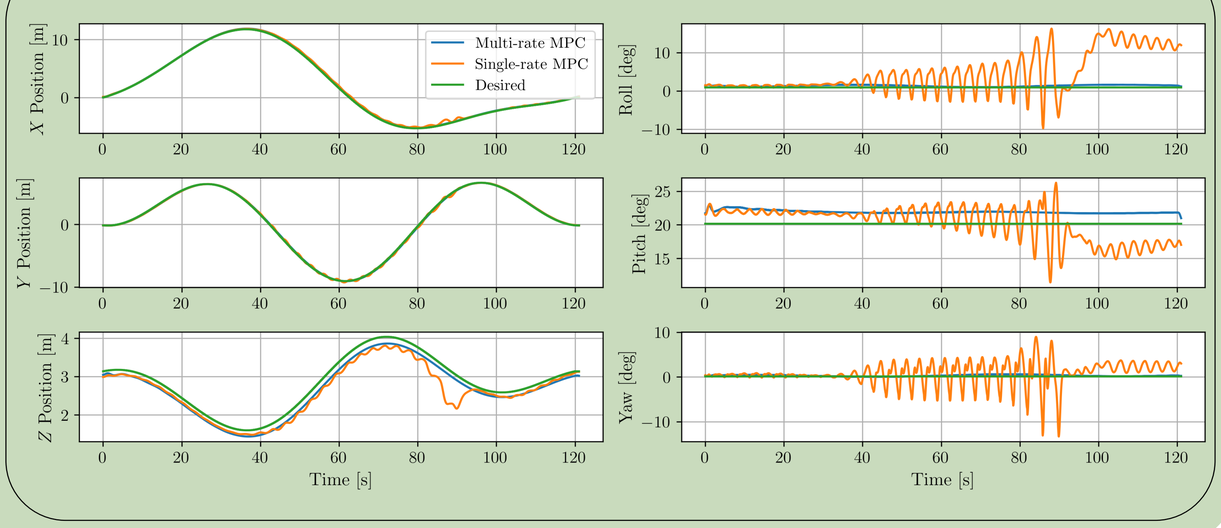
Real-time feasibility:
MPC solves on average in 2.18 ms (it can run at 200 Hz).

Ablation studies:
- Without Jet Dynamics → failure.
- Without LPV → failure.
- Without multi-rate → larger errors, oscillations.

Disturbance Recovery



Trajectory Tracking



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