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# Online DNN-driven Nonlinear MPC for Stylistic Humanoid Robot Walking with Step Adjustment

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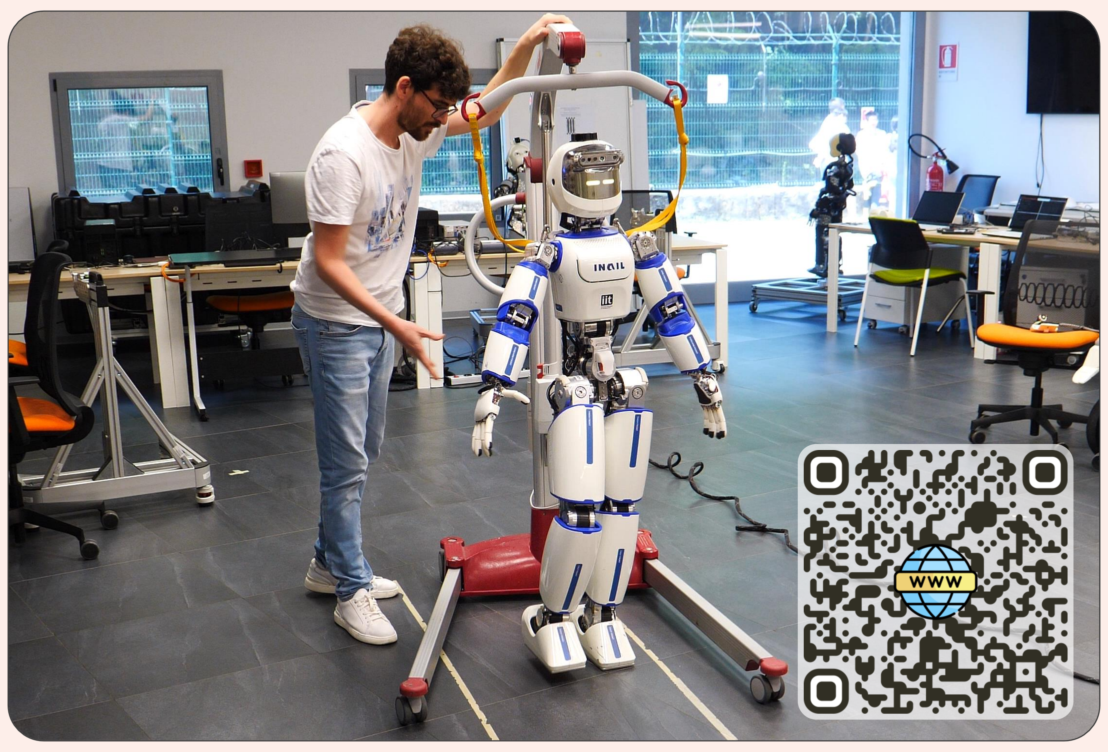
## Key points

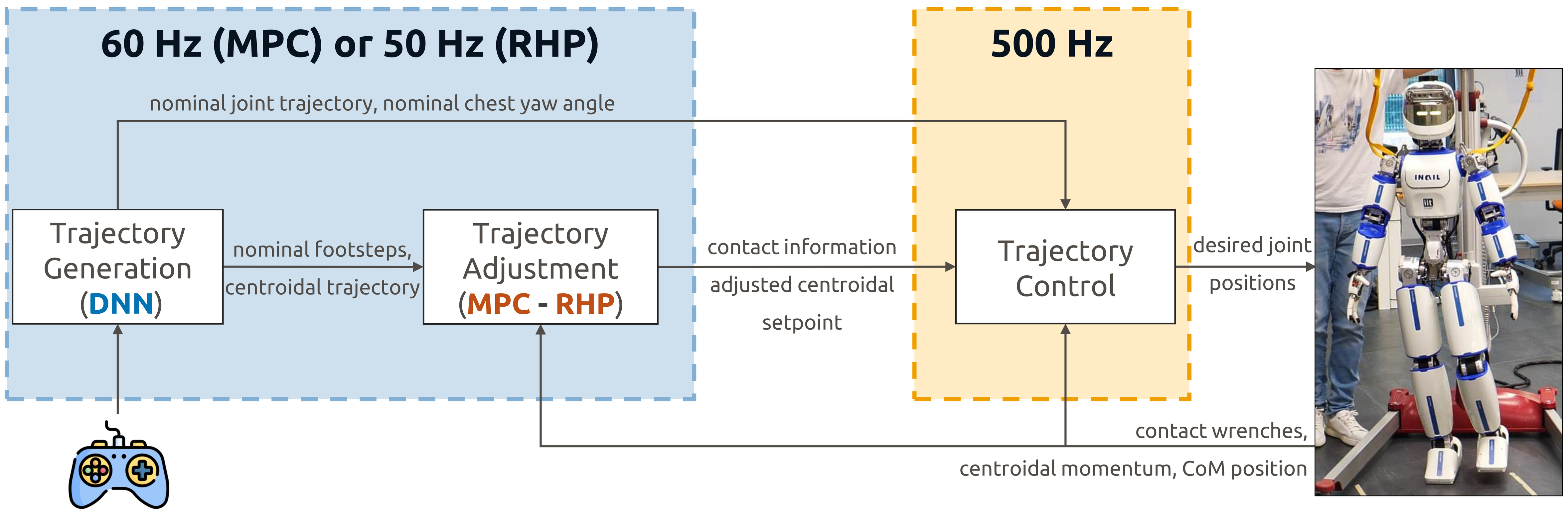
**Goal**: enable **stylistic humanoid** locomotion with real-time step adjustments to prevent falls and respond to disturbances, using **a hybrid data-driven and model-based control architecture**.

**Solution**: a **three-layers control system** that integrates **DNN**-driven trajectory generation with non-linear **MPC** for real-time step adjustments and stability.

**Result**: achieved **human-like walking**, balance under **disturbances up to 68N**, and reliable step adjustments on the ergoCub robot.



## Method overview




**Three-Layers Architecture**: integrates a **DNN** for human-like trajectory generation and a trajectory adjustment layer for **real-time step adjustment**.

**Interconnection Challenges**: manages **contact awareness**, **time horizon alignment**, and **frequency sync** between DNN and MPC / RHP.

**Noise Reduction**: when using MPC, a **GA-Kalman filter** reduces centroidal measurement noise.

## Challenges

### Challenge 1: Contact Awareness

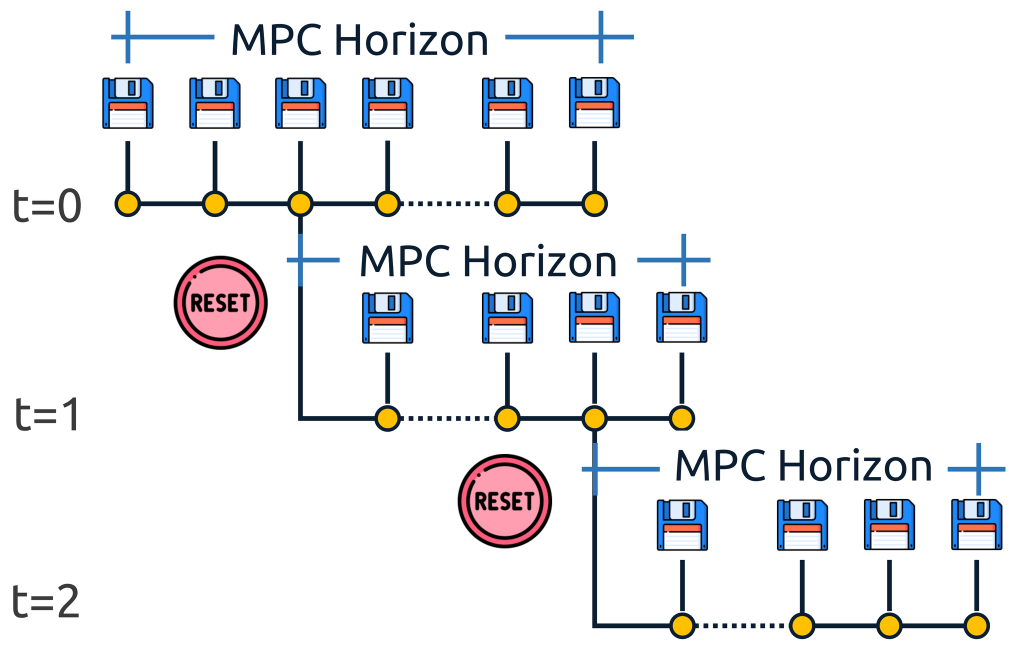
**Extracting Contact Data**: DNN lacks **explicit contact** states, necessary for stable adjustments.

**Contact Detection**: a **Schmitt trigger** identifies active contacts from DNN output.

**Position Adjustment**: **contact locations** are **scaled** to ensure feasibility:

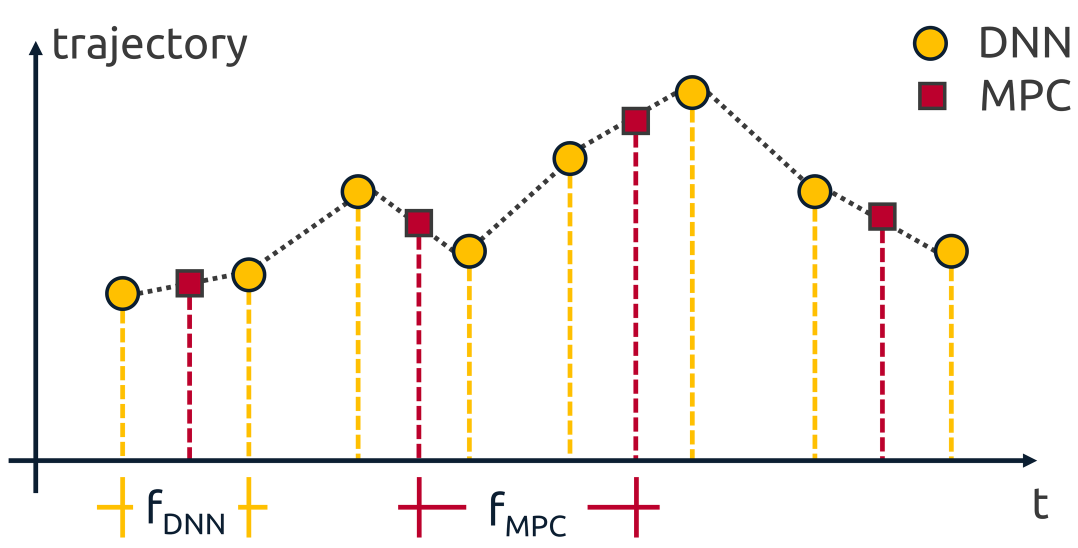
$$p^s_{\circ_i} = p^s_{\circ_{i-1}} + \gamma(p^n_{\circ_i} - p^n_{\circ_{i-1}})$$

### Challenge 2: Time Horizon Alignment




### Challenge 3: Frequency Synchronization

**Trajectory resampling**: we **resample** the trajectory with a first order spline.

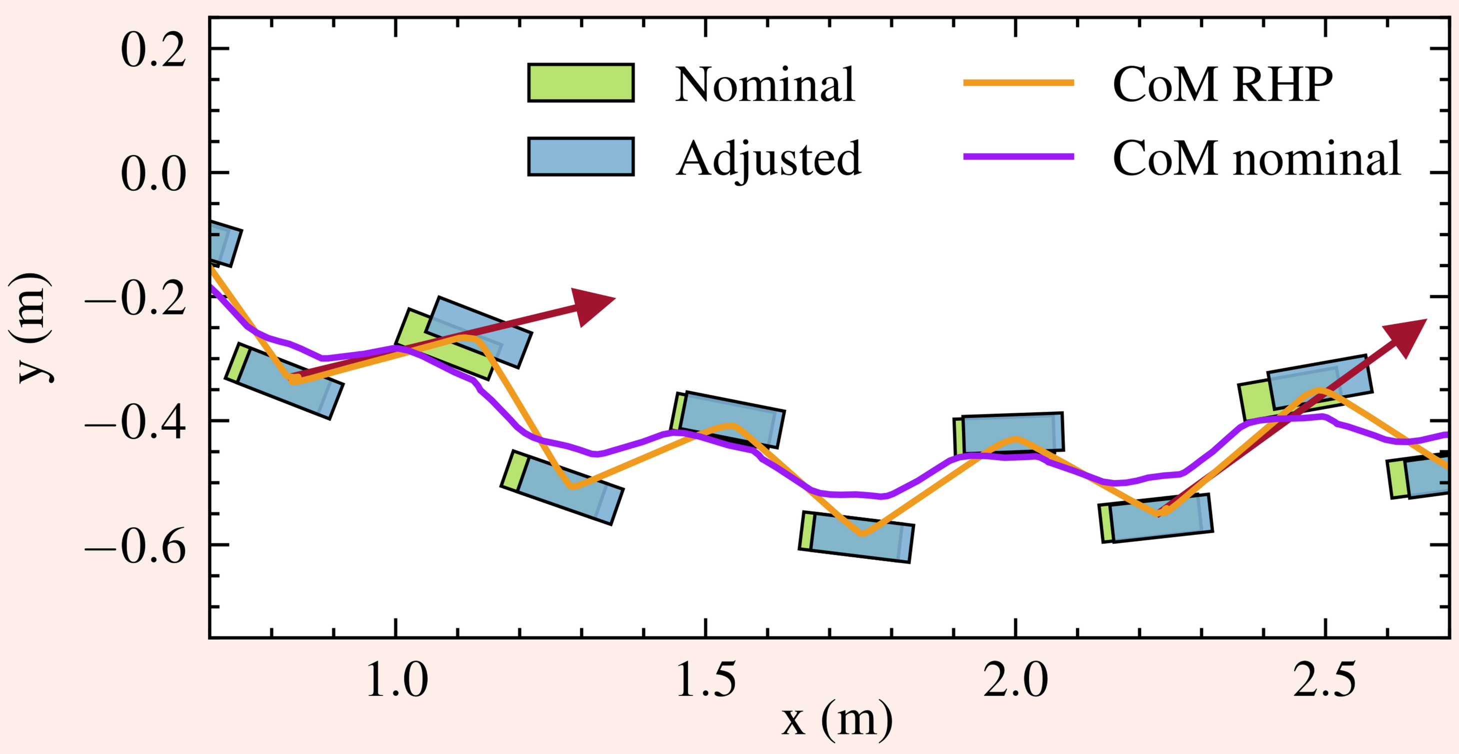



## Results

### Trajectory adjustment as RHP

**Experiment**: evaluated **without considering the robot's centroidal state**, adjusting steps under perturbations but with limited adaptability.

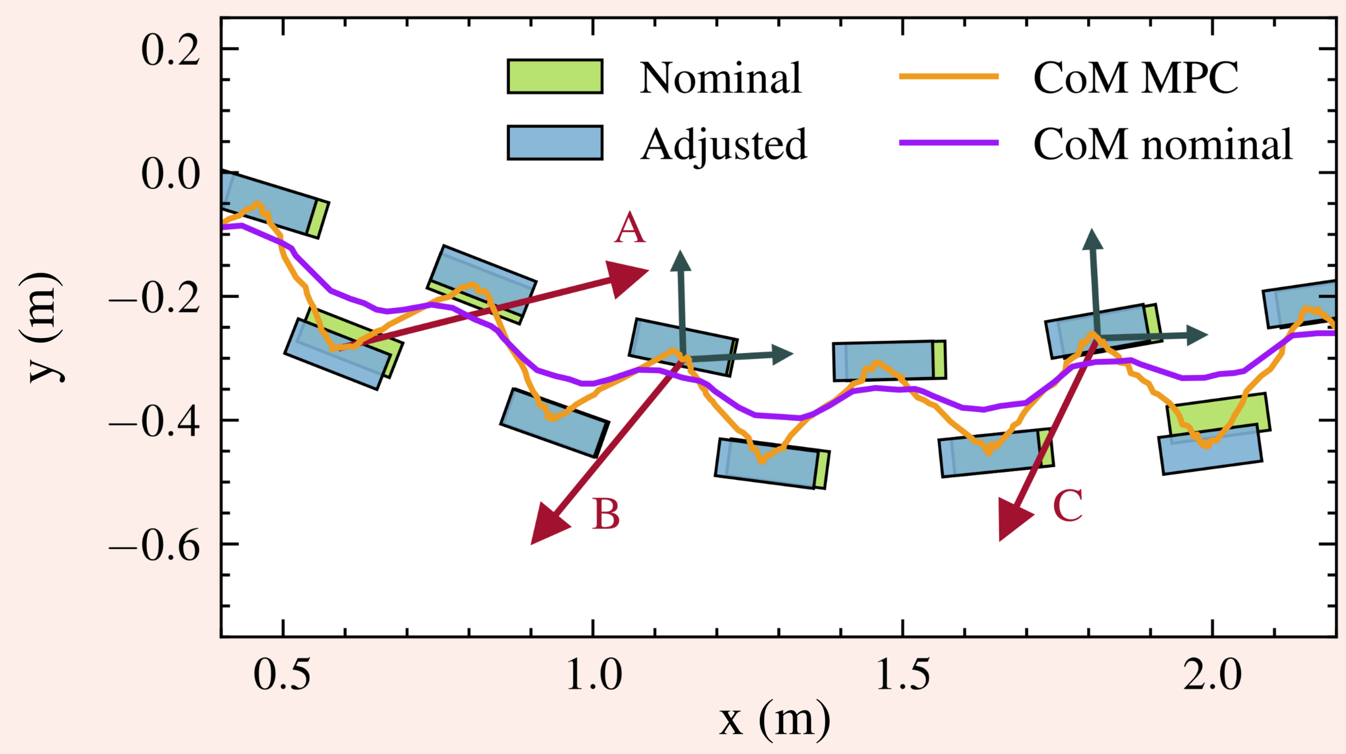
**Comparison**: uses **desired quantities for feedback**, avoiding measurement noise but **needing force measurements for disturbances**.




### Trajectory adjustment as MPC

**Experiment**: tested with **real-time kinematic feedback**, showing high adaptability to external perturbations.

**Comparison**: uses kinematic feedback, **avoiding force measurements** but requires **GA-tuned Kalman filter for joints velocity** noise reduction.

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