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Intelligent Motion Control under Industry4.E

Multi-objective tuning for torque PD controllers of collaborative robots

Diego Navarro Cabrera, UGR – diegonavaca@ugr.es

Niceto Luque Sola, UGR – nluque@ugr.es

Eduardo Ros Vidal – eros@ugr.es

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Context

- Industrial robots are too dangerous for Human-Robot Interaction (HRI)
- Collaborative robots (cobots) add safety measures (p.e. sensors and elastic joints) to accommodate a safer HRI.
- Lack of structure in HRI tasks and the complex non-linearities of elastic joints hinder the use of traditional control algorithms.

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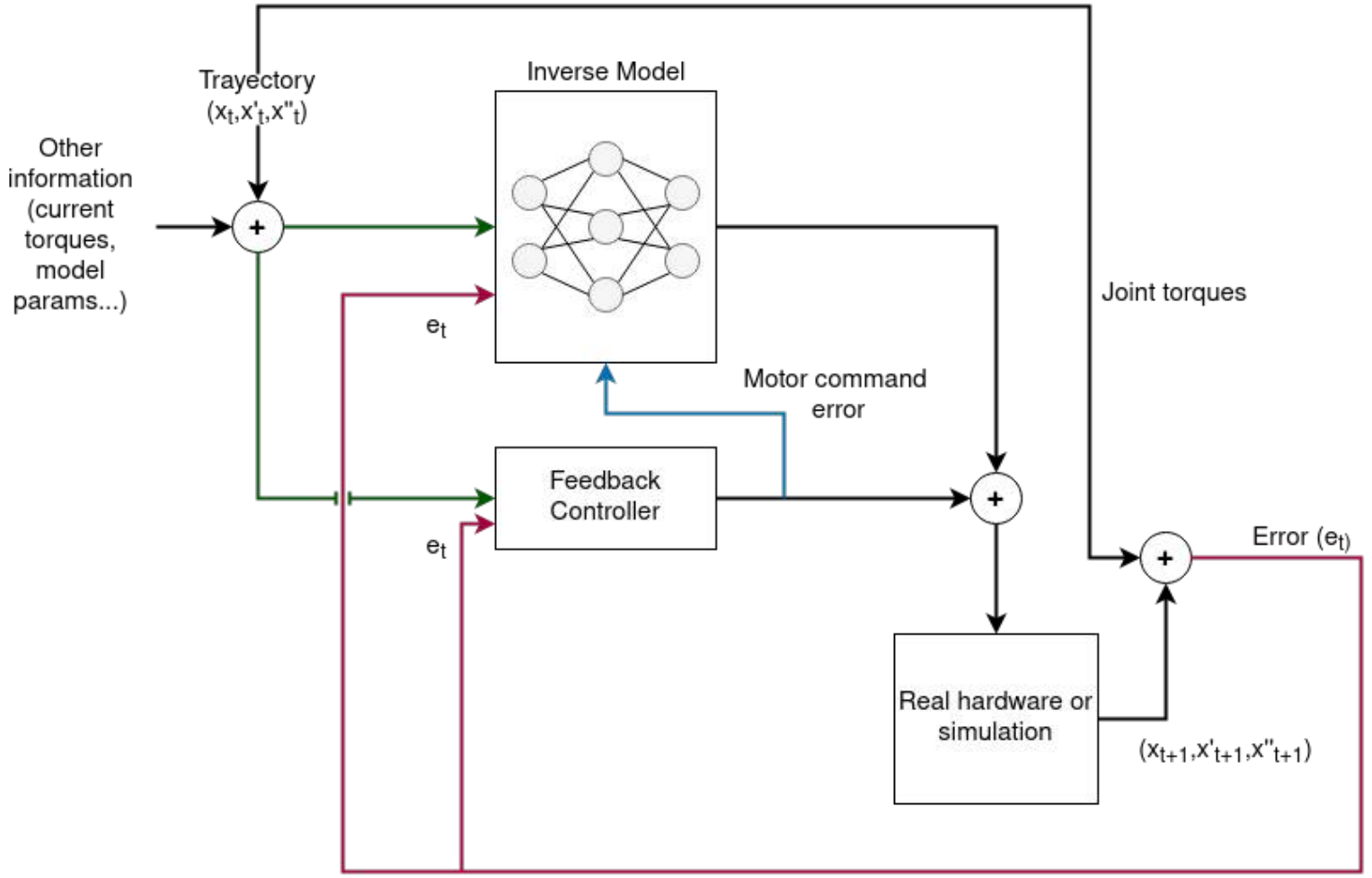
Context

- Machine learning (ML) is used to make data-driven dynamic models to improve control accuracy.
- Many works use reinforcement learning to create a model from scratch, but this usually faces sim-to-real challenges.
- Creating a dataset is not a trivial task but can be highly valuable



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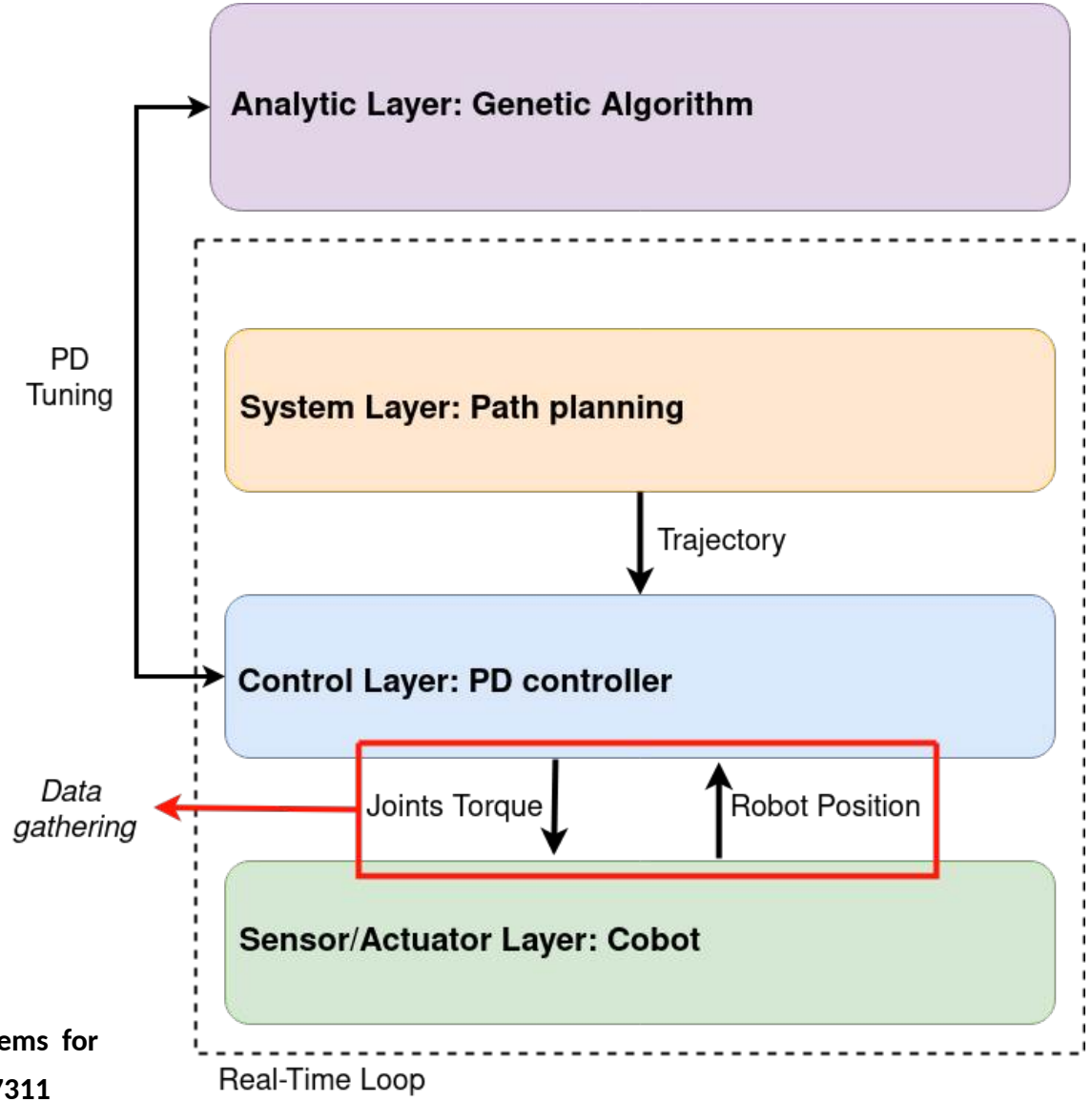
Methodology: Framework

Objective:

Use PD controllers to gather data from a set of representative trajectories.

To tune the controllers we will use **multi-objective genetic algorithms** to balance the **safety** and **accuracy** of the controller.



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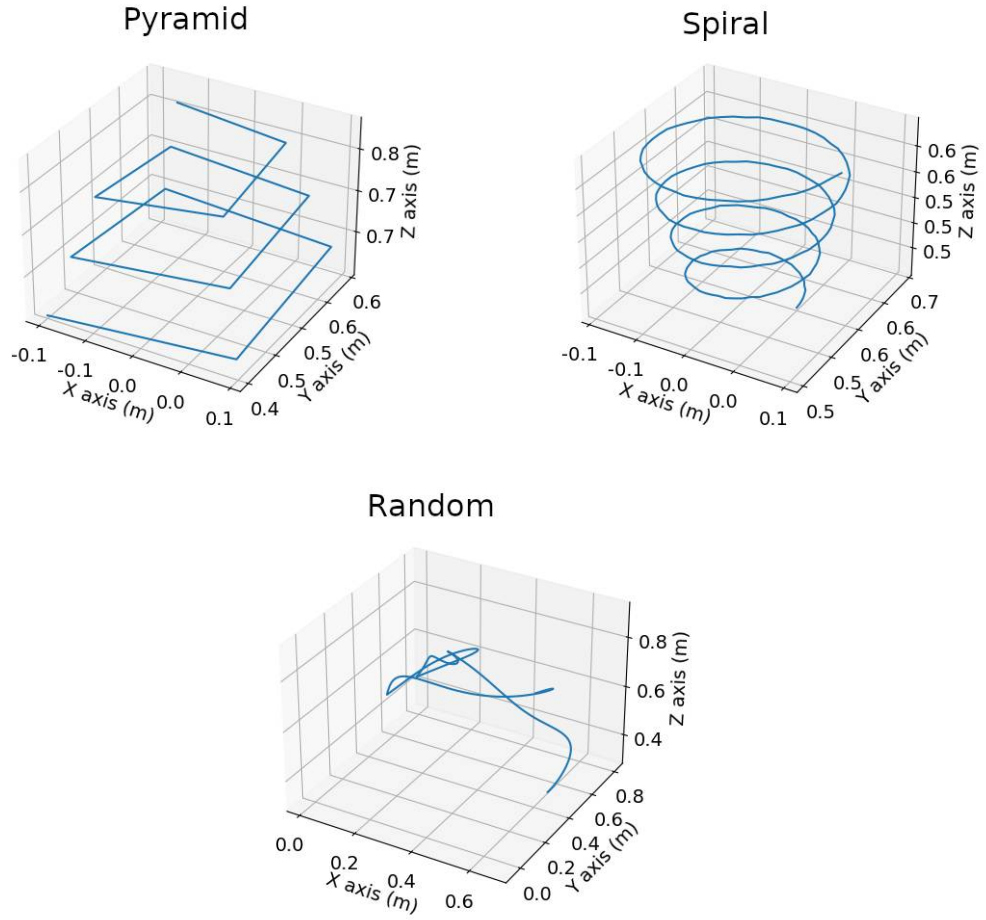
Methodology: Trajectories



- Building upon [1] we propose the use of both pyramid and spirals, coupled with some random trajectories to cover all kinds of movements in the dynamic model.
- Both pyramid and spirals are performed on the 3 axis of the cartesian space

[1] Valencia-Vidal, B., Ros, E., Abadía, I., Luque, N. R. Bidirectional Recurrent Learning of Inverse Dynamic Models for Robots with Elastic Joints, A real-time real-world implementation. Frontiers in Neuro-robotics, 17, 1166911.

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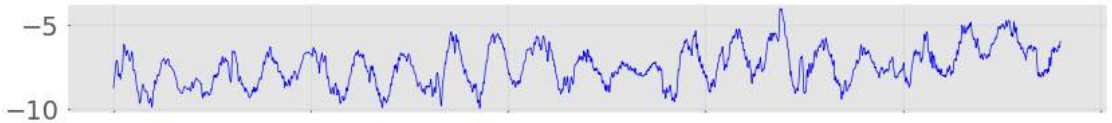
Methodology: Objective Functions

Accuracy Function:

Mean Euclidean distance of the effector to the desired setpoint.

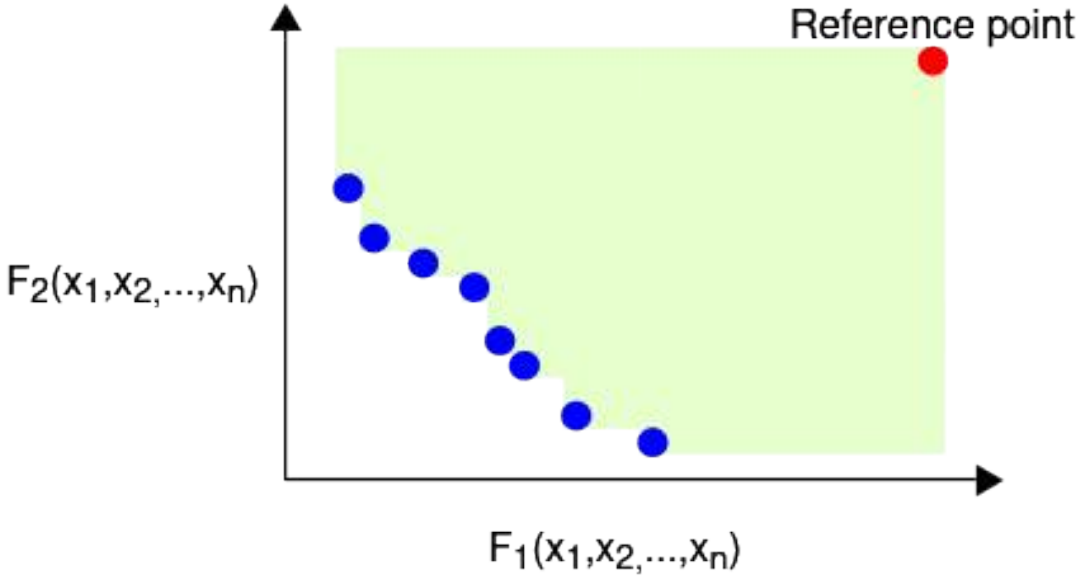
Safety Function:

$$f_t(U) = \frac{1}{T}\sum_{i=1}^{T}(u_i - u_{i-1})^2$$



Pareto comparison metric:

Hypervolume Indicator: area between a reference point and the pareto front.



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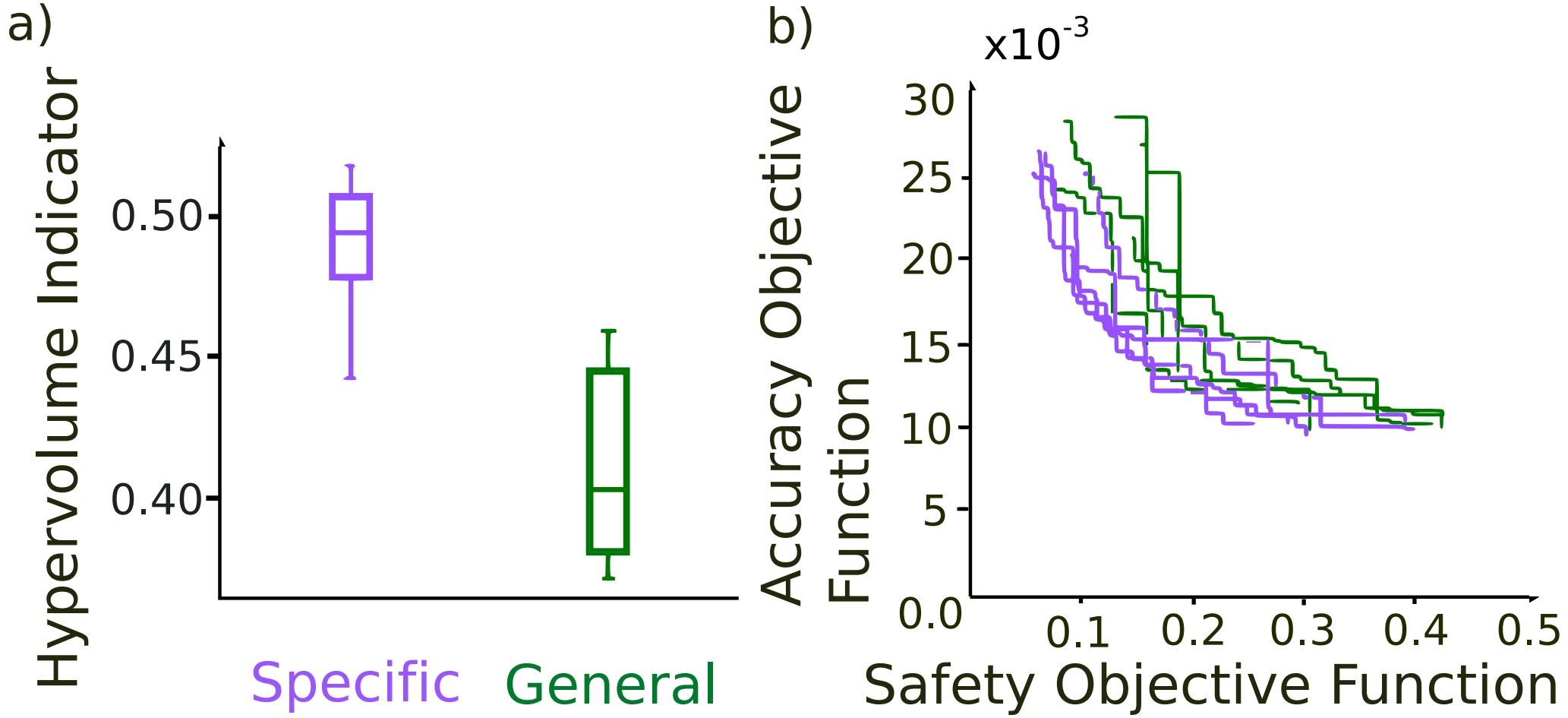
Results: Specific/Generic controller



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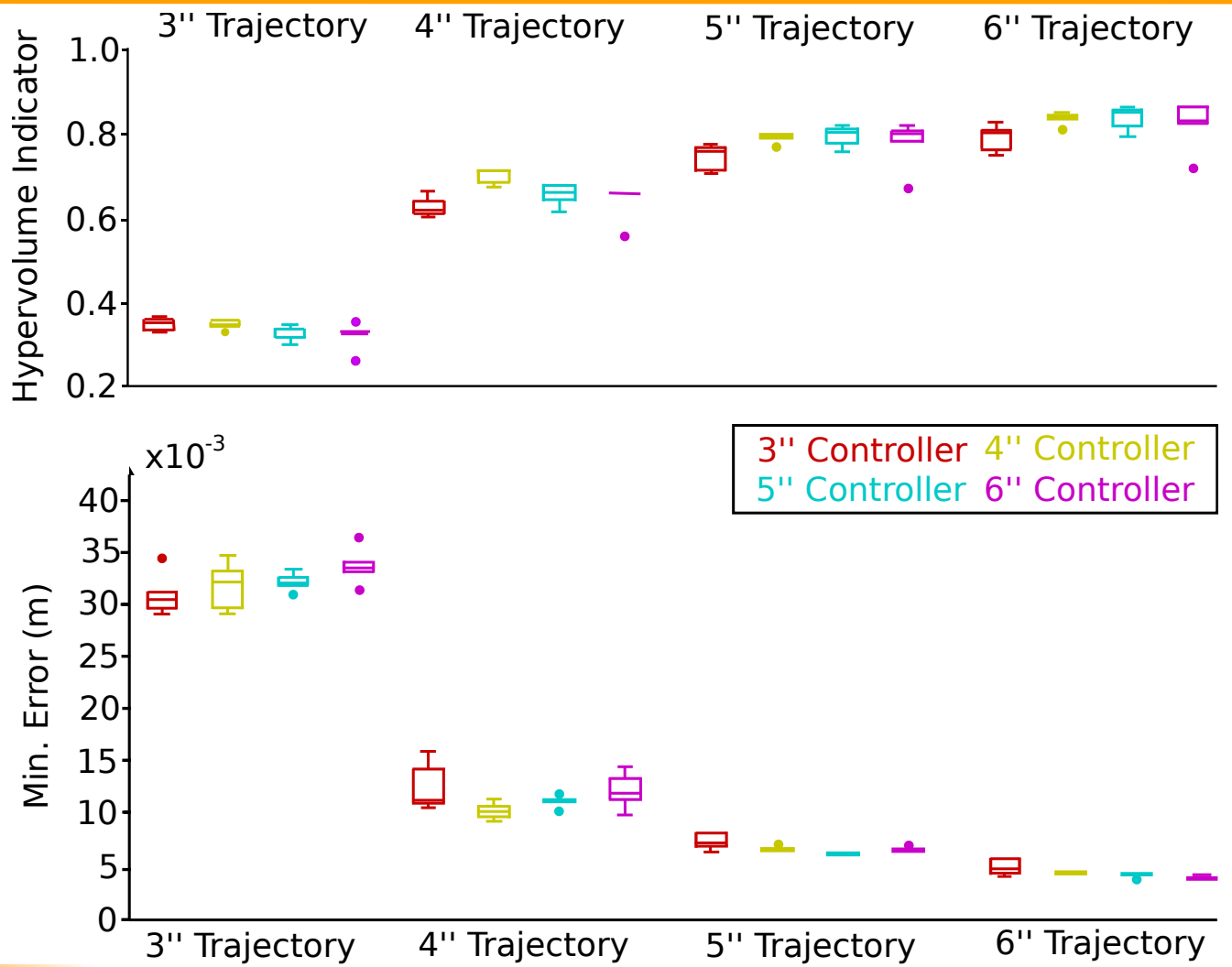
Results: Time comparison

- Trajectory speed greatly influences cobot dynamics.
- If the trajectory is too fast, control won't be accurate.
- If the trajectory is too slow, non-linearities in the dynamics won't be remarcable and there won't be much difference with traditional control.



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Conclusions and Future Research

Conclusions

- Data gathering for dynamic modelling is not an easy task, full of challenges and design decisions to take into account but it can help us make the development of new models independent from the use of the real machine, alleviating the wear on the robot and reducing the risk of malfunctions during training.

Future Research

- This methodology still has to be validated and applied in real hardware.
- Other aspects of the methodology, such as the genetic algorithm used could be further studied and validated.

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Thank you for your attention

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