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Active Robot Learning for Efficient Body-Schema Online Adaptation

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Motivation

The aim of this work is to estimate the body-schema parameters (DH parameters) of 7 joints of the iCub arm, using an Extended Kalman Filter and active learning for movement and sampling efficiency.

Robots rely on their body-schema to be able to predict the location and orientation of their body parts.

Online body-schema learning:

- Allows the robot to adapt to accumulated errors.
- Increases robot's autonomous time.

Active learning methods have been successfully employed to optimise the number of training samples for learning tasks.

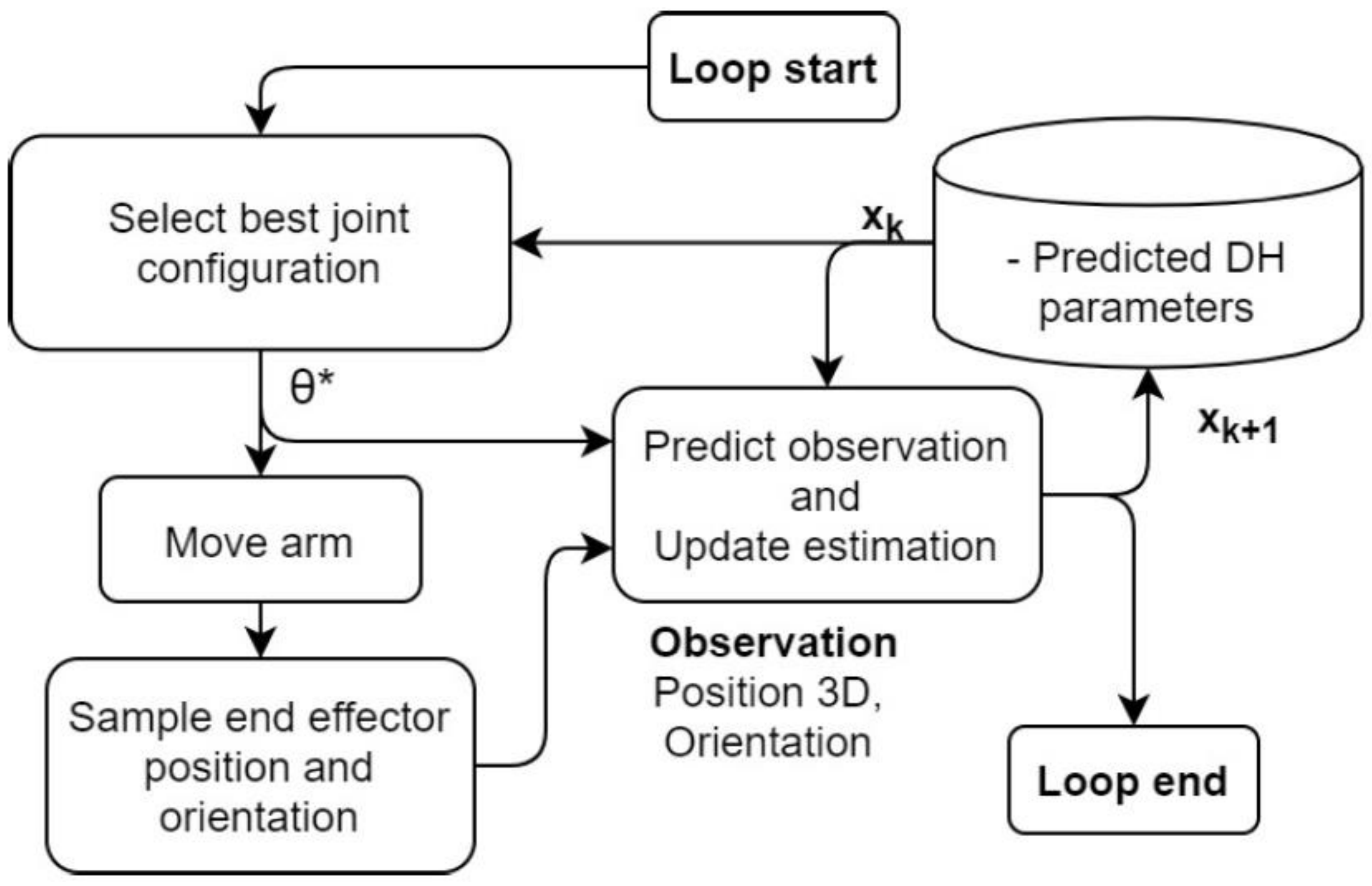
DH Parameters Estimation

The DH parameters are denoted by:

$$\boldsymbol{x} = \left[\boldsymbol{DH}^{(0)};\ \boldsymbol{DH}^{(1)};\cdots;\boldsymbol{DH}^{(6)}\right],$$

where $\boldsymbol{DH}^{(i)}$ is a vector of size 4, containing the DH parameters of the ith joint.

Estimation done using an Extended Kalman Filted (EKF).
Main loop of the algorithm:



Cost-Sensitive Active Learning

This work aims to choose joint configurations to sample the end-effector pose to reduce:

- Body-schema error
- Movement performed while calibrating.

It achieves these objectives by:

- Selecting joint configurations, minimising the cost function

$$C(\theta) = \mathbb{E}\left[tr(P_{k+1})|z_{1:k},\theta_{1:k}\right]$$

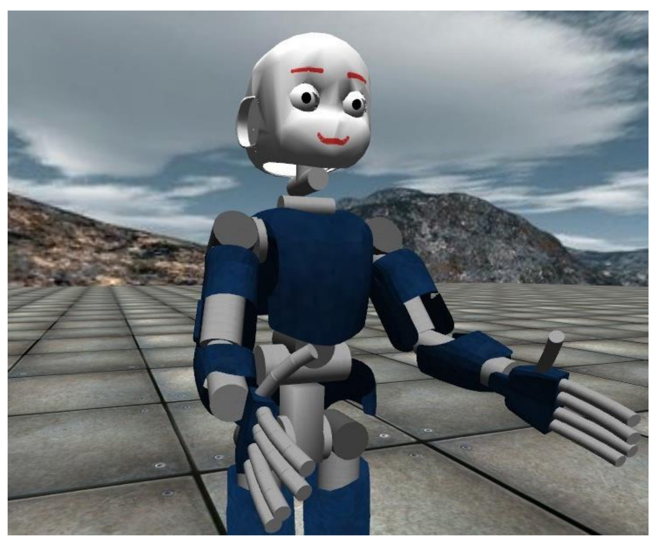
- Adding constraints to the optimisation problem

$$\theta_k^* = \underset{\theta\in\left[\theta_{k-1}^*-\Delta,\theta_{k-1}^*+\Delta\right]}{\operatorname{argmin}} C(\theta)$$

$$\Delta = \delta \cdot \mathbf{1}_n$$

Results

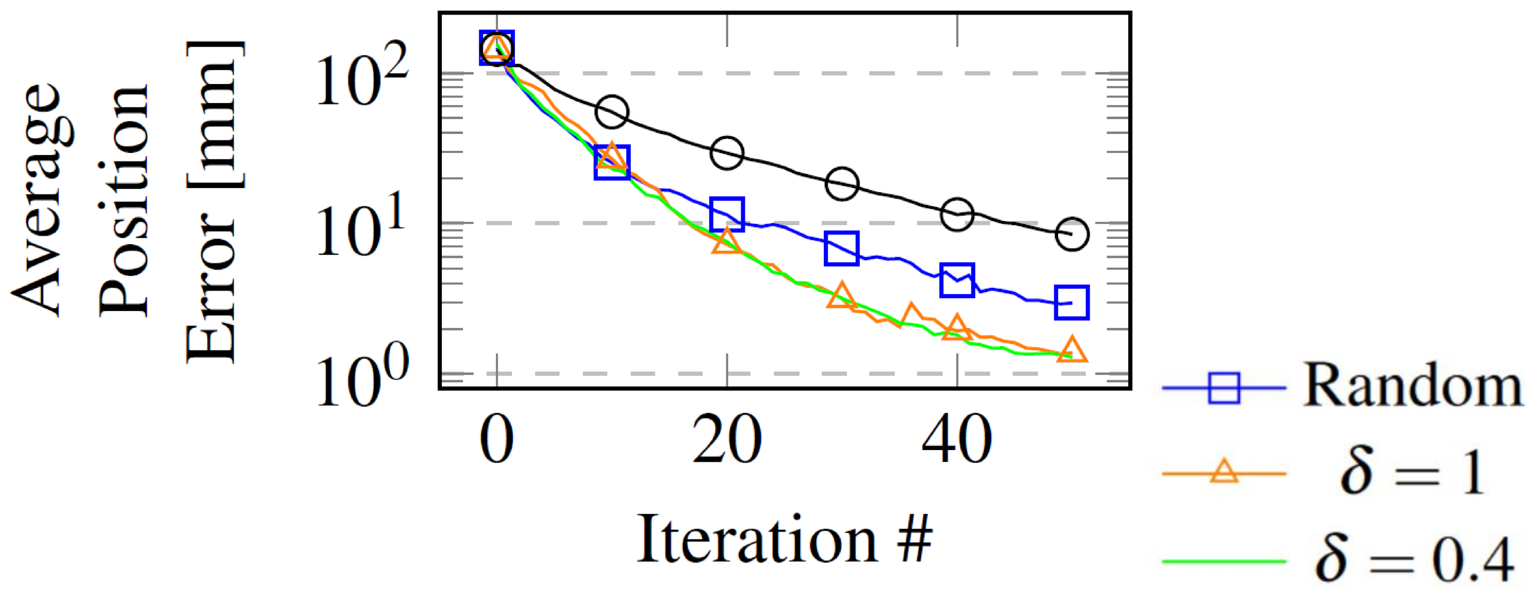
We compared the performance of the proposed method with **random sampling** and **active learning with no movement restrictions**.

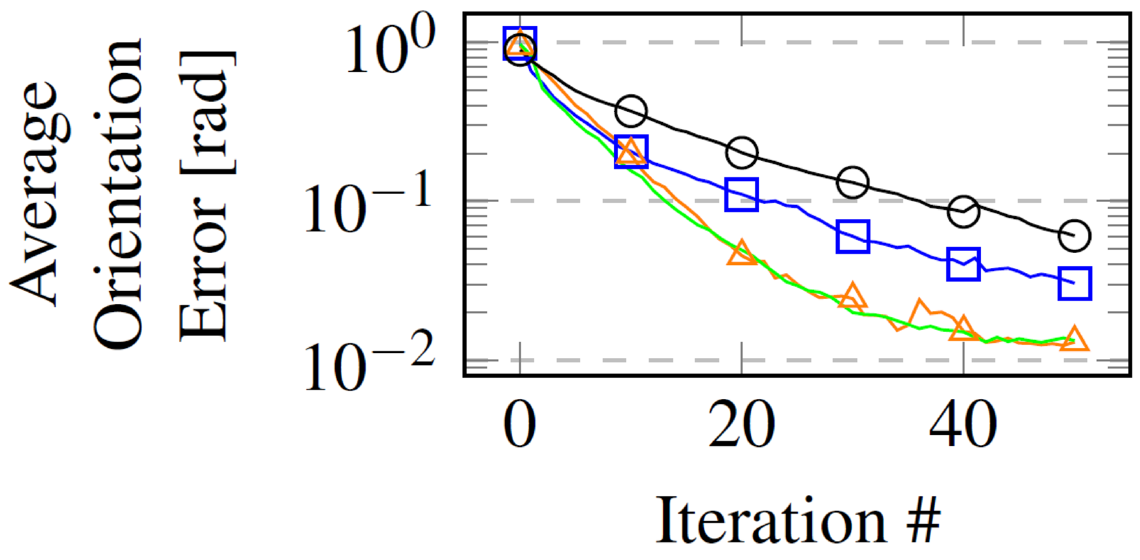


The **position** and **orientation errors** are computed between the actual and predicted poses of the end-effector.

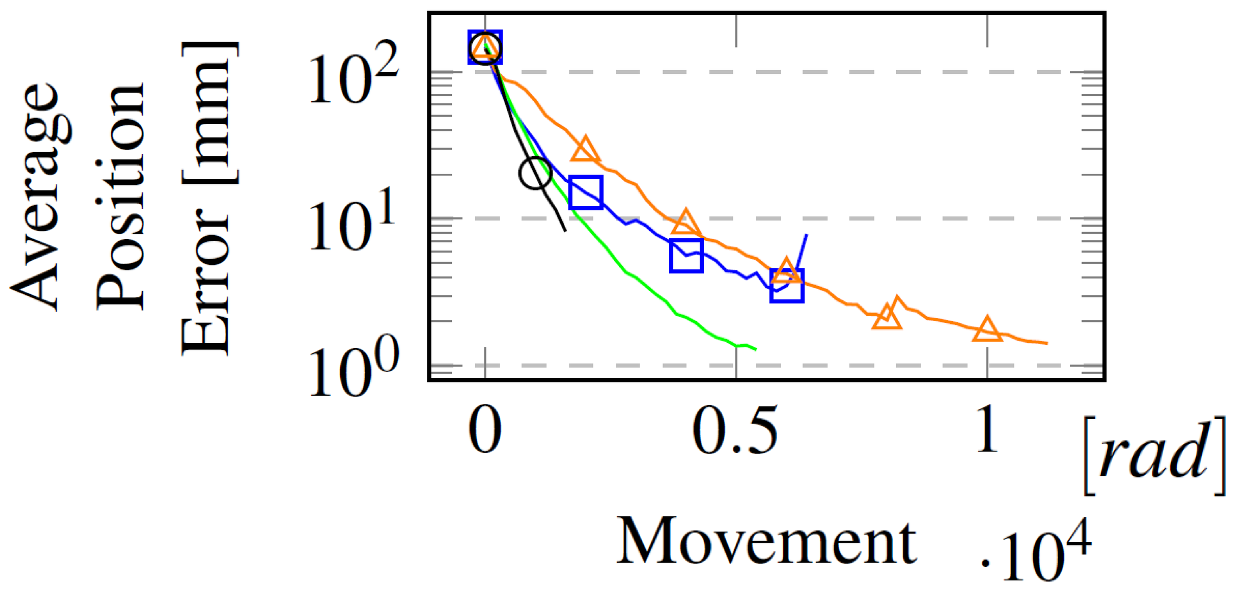
The error evolution was evaluated

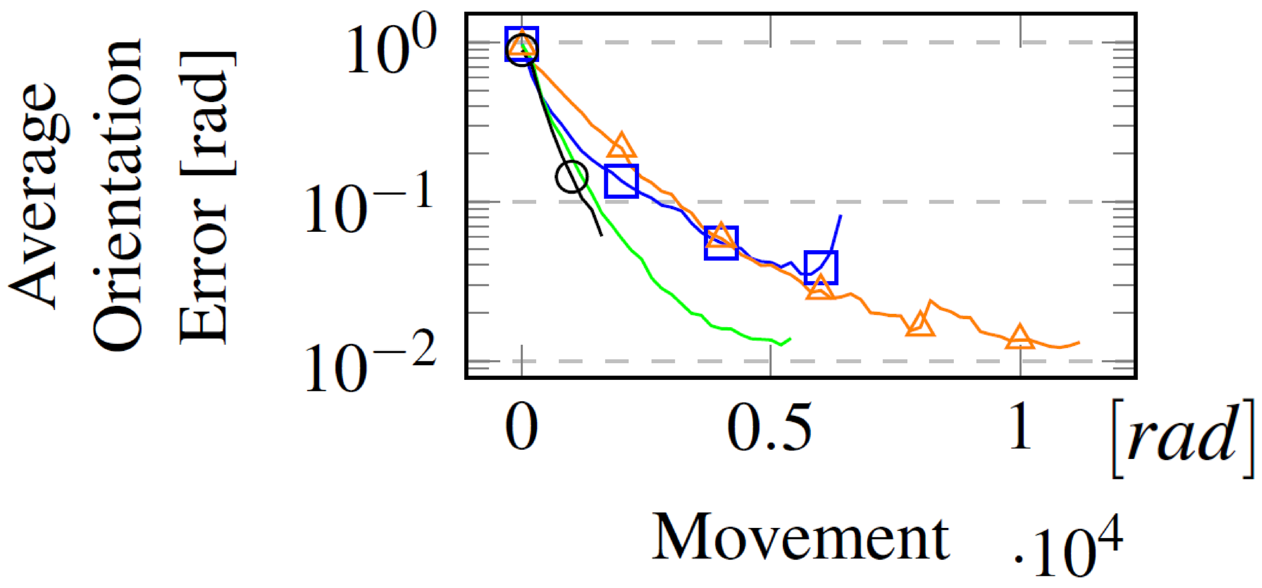
- At each iteration to perceive the quality of the samples:





- With respect to movement performed by the arm joints to perceive the movement efficiency:





Conclusions

Movement restrictions → Significant efficiency gain → Low performance impact

FCT Fundação para a Ciência e a Tecnologia

This work was supported by FCT with the LARSyS - FCT Project UIDB/50009/2020 and the PhD grant PD/BD/135115/2017.

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