Human preferences' optimization in pHRI collaborative tasks

Paolo Franceschi[1,2], Marco Maccarini[3], Dario Piga[3], Manuel Beschi[2], Loris Roveda[3]

[1] CNR-STIIMA, via Alfonso Corti 12, 20148, Milano, Italy
[2] University of Brescia, Via Branze, 38, 25123, Brescia, Italy
[3] IDSIA-SUPSI, Via la Santa 1, 6962, Lugano, Switzerland

Motivations and objectives

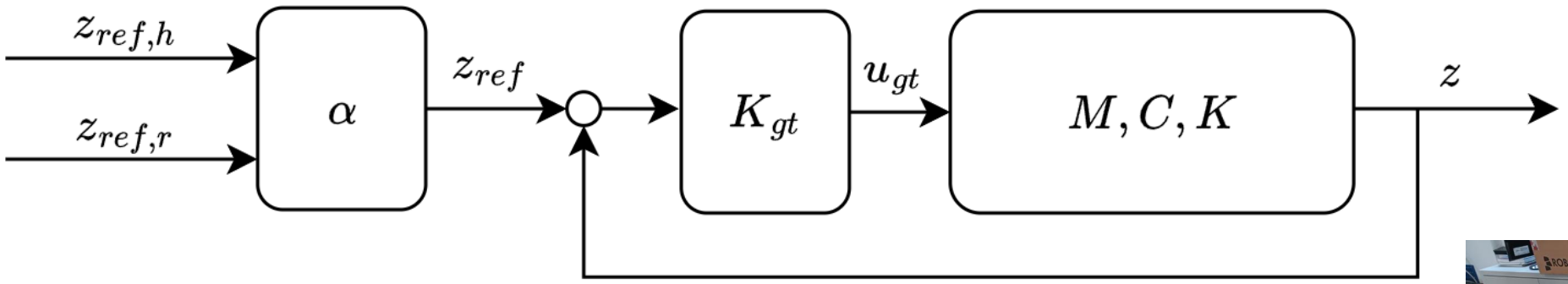
Motivations:

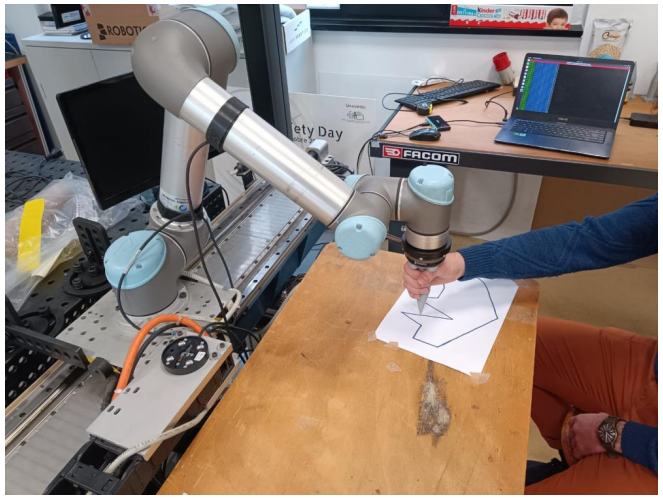
- Human-Robot Interaction performances are subjective
- Same controller with different parameter tuning
- Tuning according with the human preferences

Objectives:

- Define a procedure to tune a pHRI controller according to each subject's preferences
- Evaluate general human behaviors and preferences according to different tasks and requirements

GT Cooperative controller

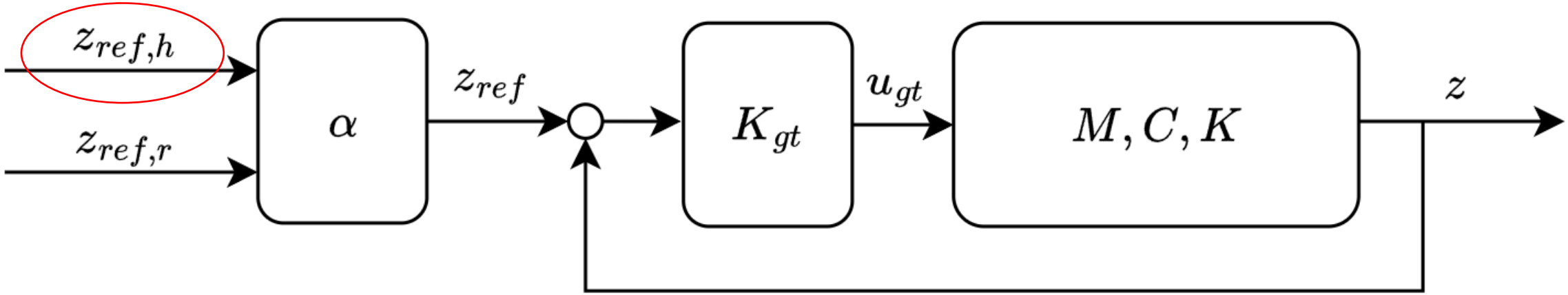




GT Cooperative controller

Human intention prediction

$$z^{+}_{ref,h} = z^{-}_{ref,h} + K_{p,h}u_h$$



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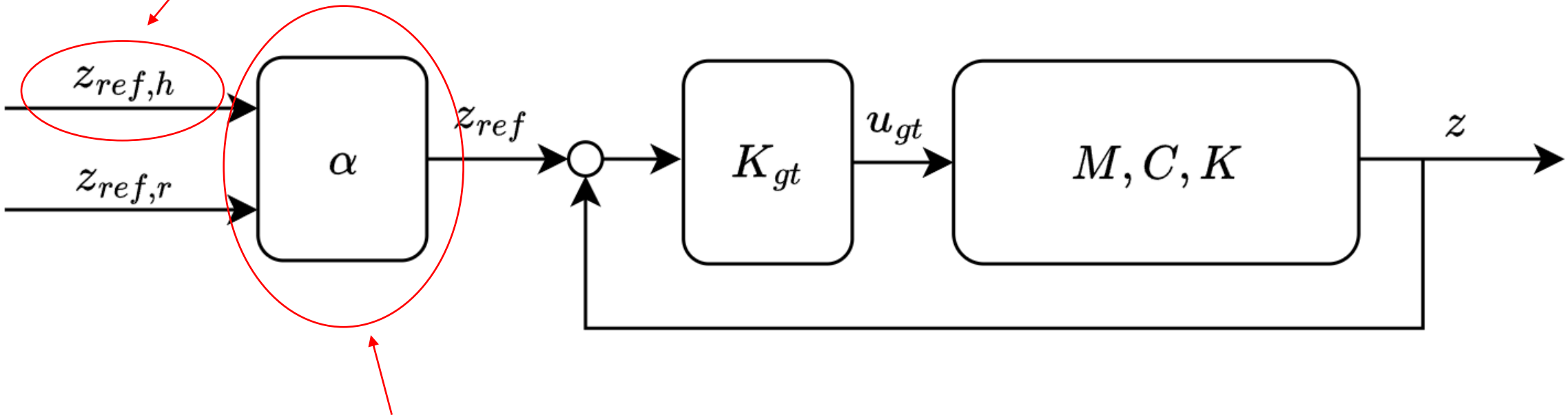
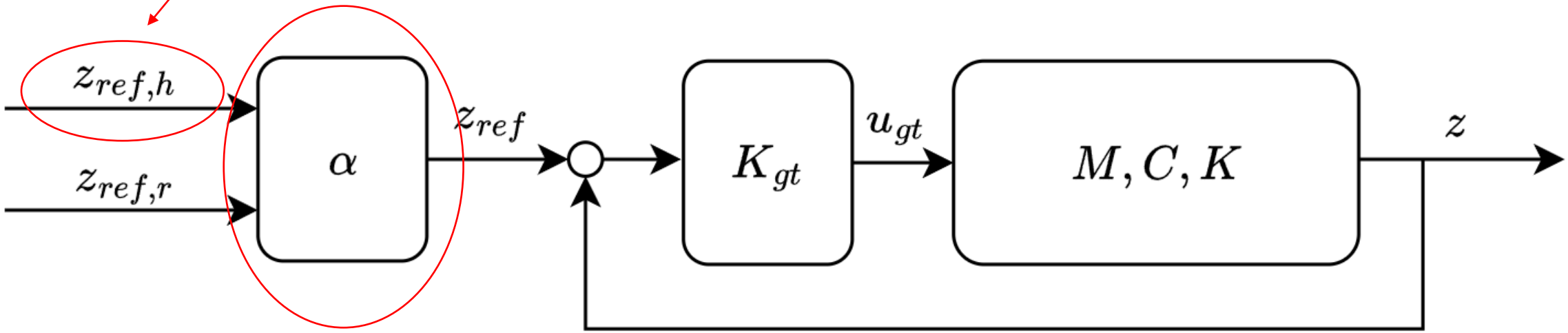


Bargaining problem: find cooperative cost function depending on α, $J_{GT} = \alpha J_h + (1-\alpha)J_r$

GT Cooperative controller

Human intention prediction

$$z^{+}_{ref,h} = z^{-}_{ref,h} + K_{p,h}u_h$$



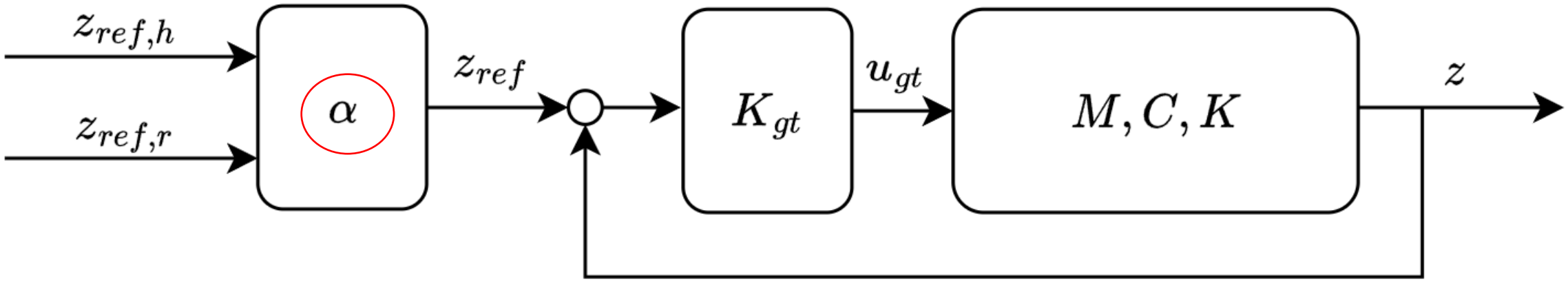
$J_h = \int z^T_{ref,h} Q_h z_{ref,h} + u_h^T R_h u_h$ → from IOC

$J_r = \int z^T_{ref,r} Q_r z_{ref,r} + u_r^T R_r u_r$ → to be optimized

Optimization variables

Human intention prediction

$$z^{+}_{ref,h} = z^{-}_{ref,h} + K_{p,h} u_h$$

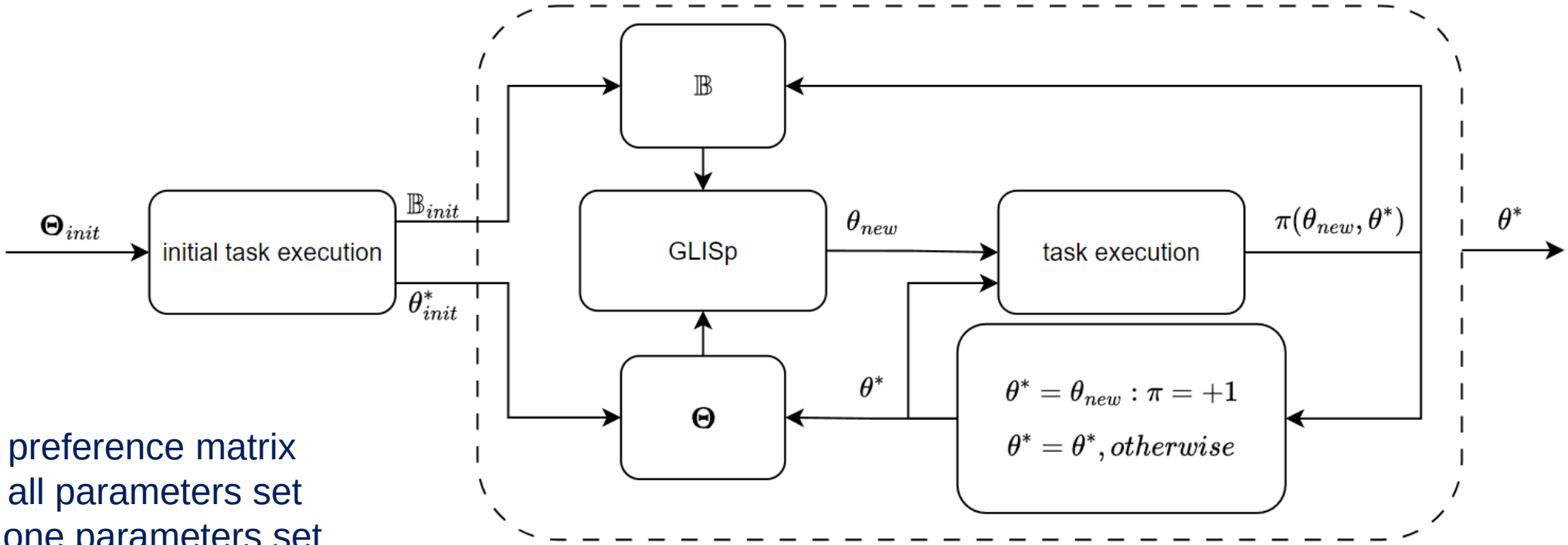


$$J_h = \int z^T_{ref,h} Q_h z_{ref,h} + u_h^T R_h u_h \rightarrow \text{from IOC}^1$$

$$J_r = \int z^T_{ref,r} Q_r z_{ref,r} + u_r^T R_r u_r \rightarrow \text{to be optimized}$$

[1]P. Franceschi, N. Pedrocchi, and M. Beschi, “Inverse optimal control for the identification of human objective: a preparatory study for physical human-robot interaction,” in 2022 IEEE ETFA, 2022

PBO with GLISp[2] algorithm



$\mathbb{B}$: preference matrix
$\boldsymbol{\Theta}$: all parameters set
θ: one parameters set
π:preference between two sets

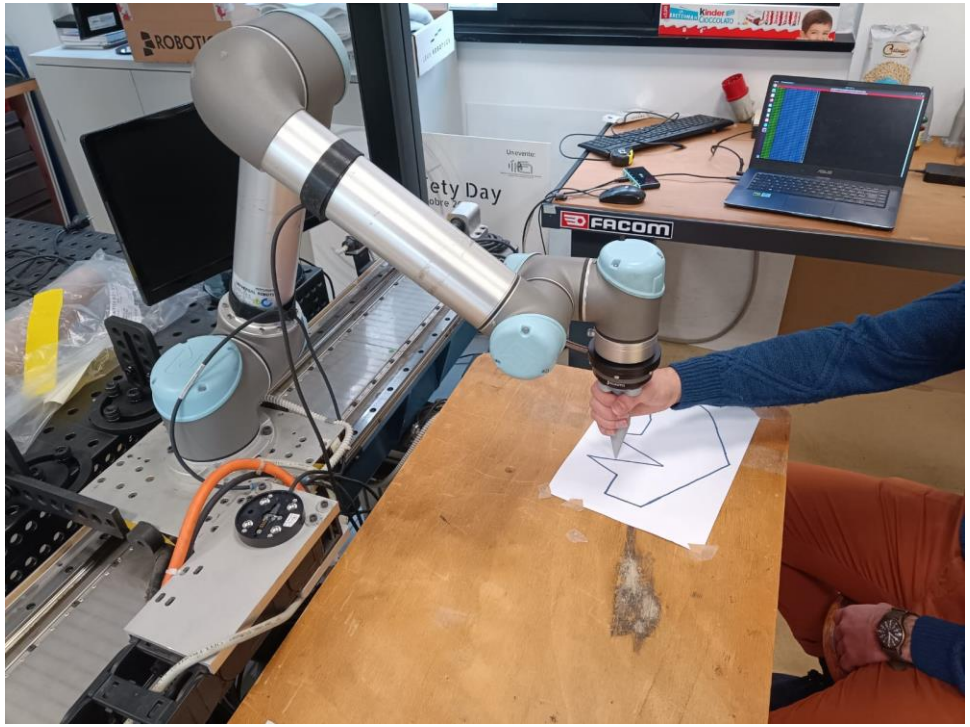
[2] A. Bemporad and D. Piga, “Global optimization based on active preference learning with radial basis functions,” Machine Learning,vol, 2021

Experiments

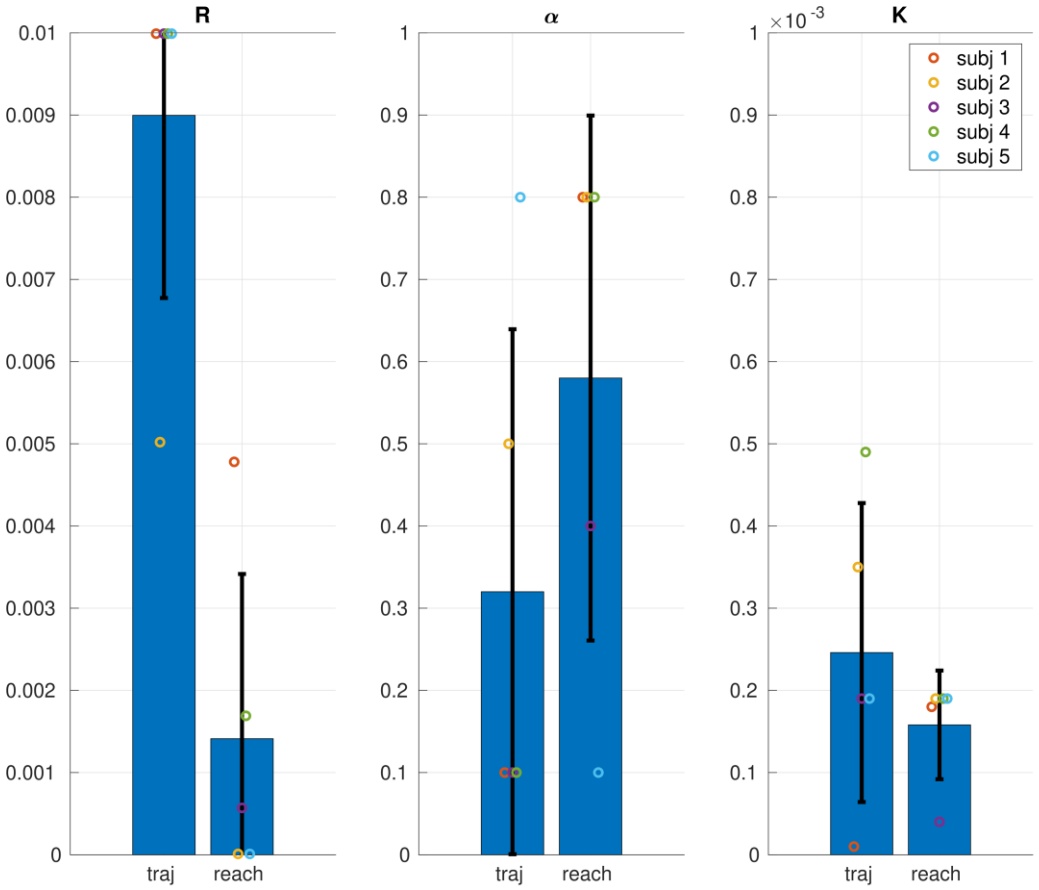
UR5 robot
Robotiq FT300 sensor
3D-printed handle
5 subjects

2 set of experiments:
. Path following
. Fast reaching

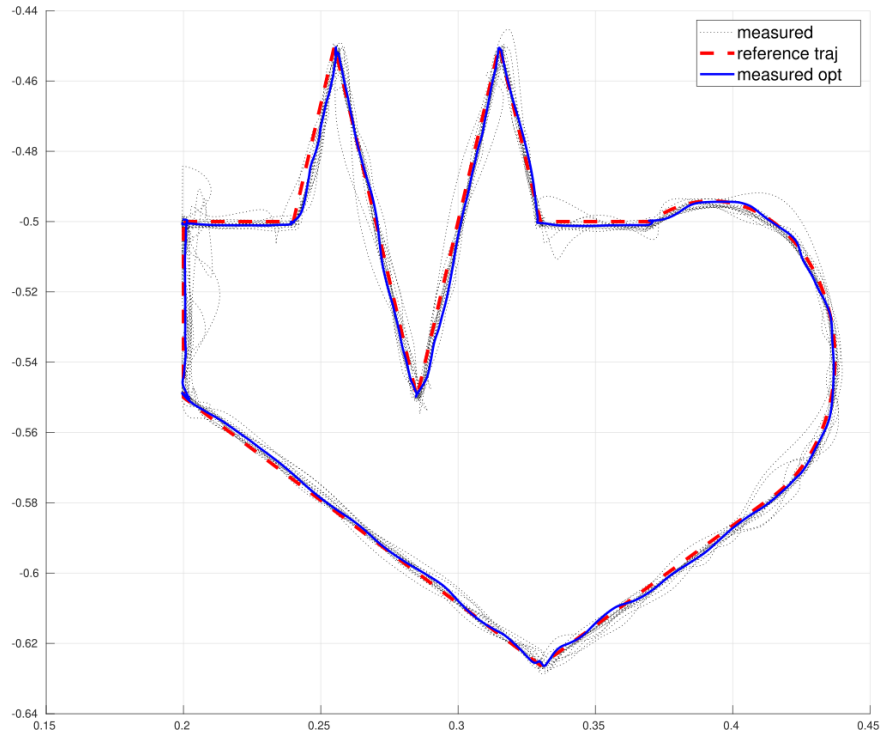
Performance idexes
. Dinamyc Time Warping (DTW)
. Force RMS
. Questionnaire

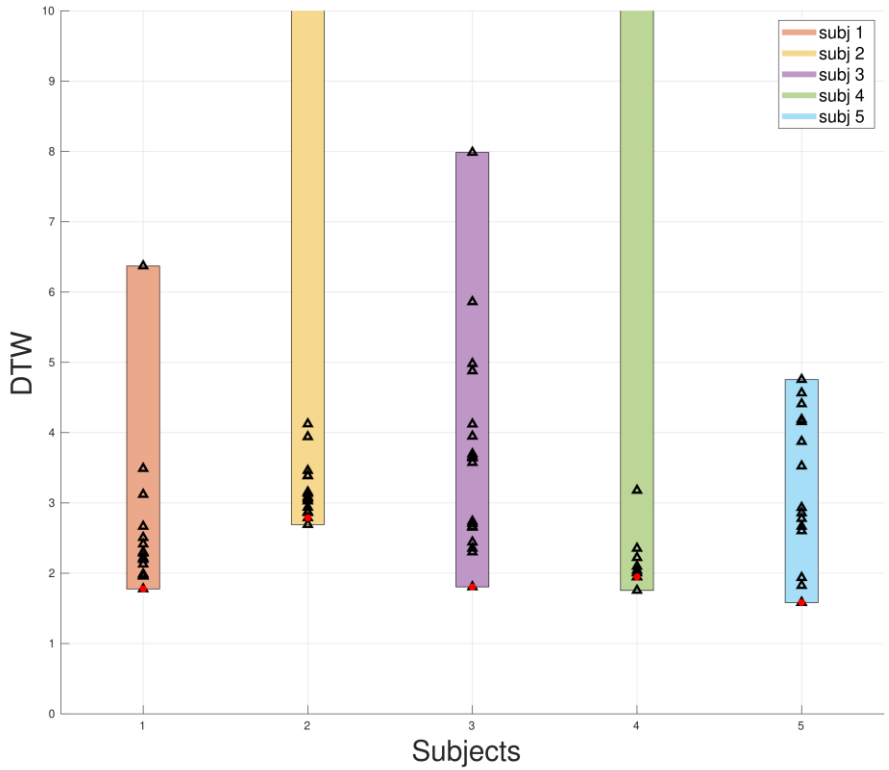


Results – optimized values

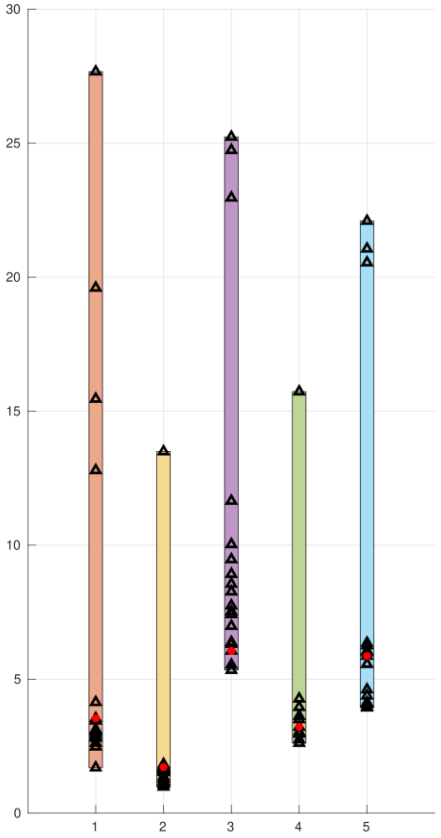


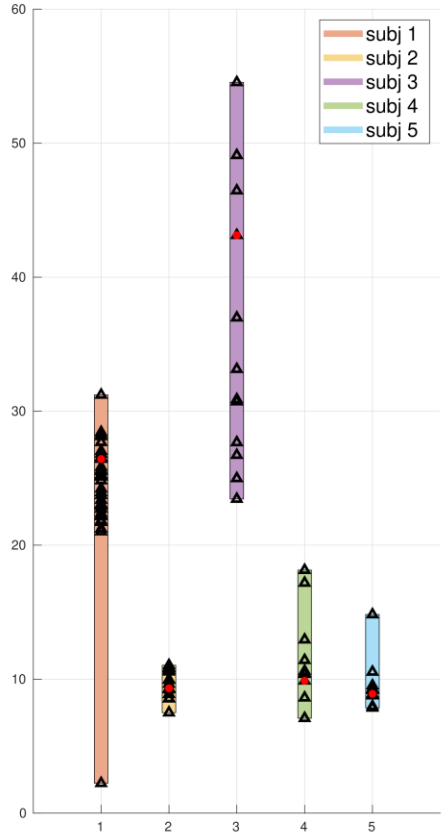
Results – DTW path following





Results – forces and questionnaire





Range [0-4]

	Long	Tiring	Satisfied
Path following	1.25	1.00	2.75
Reaching	0.75	1.00	2.75

Conclusions

- Different tasks require different tuning
- Minimum force is not always preferred by the human
- In general, the proposed framework is appreciated by the subjects for tuning the controller on purpose for a specific task

Future works:

- Make the parameters variable online according to the specific sub-task
- Tune the variable parameters law according to the subject preferences

Path following experiments

Thank you for your attention

p.franceschi@unibs.it, paolo.franceschi@cnr.stiima.it