



HAL
open science

Multi-task Optimization to Evaluate Workstation Suitability over a Population of Virtual Humans

Jacques Zhong, Pauline Maurice, Vincent Weistroffer, Francis Colas

► **To cite this version:**

Jacques Zhong, Pauline Maurice, Vincent Weistroffer, Francis Colas. Multi-task Optimization to Evaluate Workstation Suitability over a Population of Virtual Humans. JNRH 2023 - Journées Nationales de la Robotique Humanoïde, Jul 2023, Bordeaux, France. hal-04212850

HAL Id: hal-04212850

<https://hal.science/hal-04212850>

Submitted on 20 Sep 2023

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Multi-task Optimization to Evaluate Workstation Suitability over a Population of Virtual Humans.

Jacques ZHONG^{1,2}, Pauline MAURICE¹, Vincent WEISTROFFER², Jean-Baptiste MOURET¹, Francis COLAS¹
¹INRIA-LORIA, Larsen ²CEA-LIST, LSI

Contact: jacques.zhong@cea.fr

Introduction

- **Musculoskeletal disorders** (MSD) in the industry are a major health issue with important productivity losses.
- **Virtual workstations** and **digital human models** (DHM) help ergonomists prototype safer workstations with lower risks of MSD.

Scientific problems

- For a given virtual workstation and a population of workers:
- 1) How to study the **impact of the morphology** on the ergonomics?
 - 2) How to generate **behaviors adapted to each morphology**?

Main idea

Compute **workstation fitness maps** over large populations of virtual workers, by combining whole-body control and multi-task optimization.

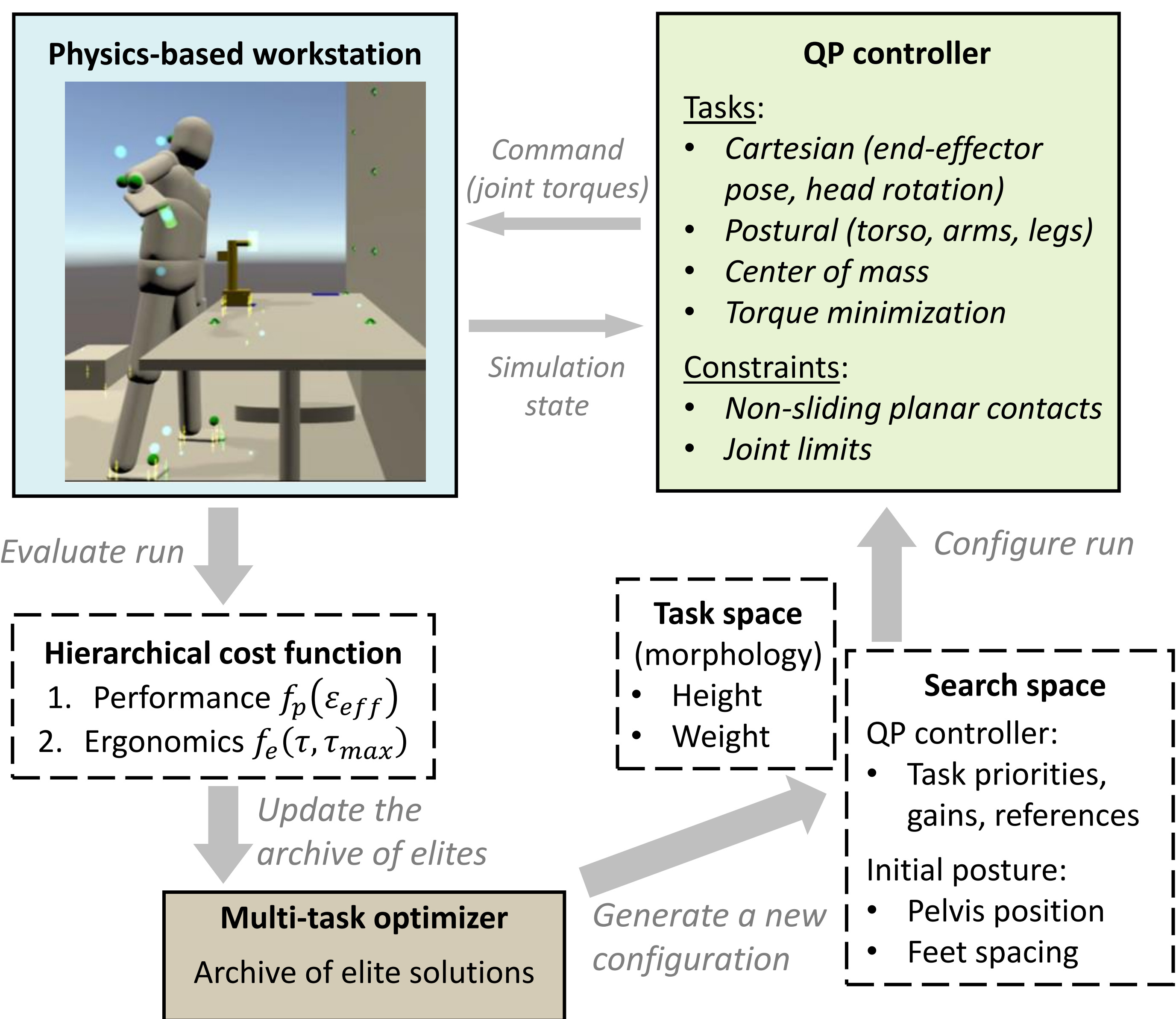
Method overview

Activity simulation with physics-based DHM:

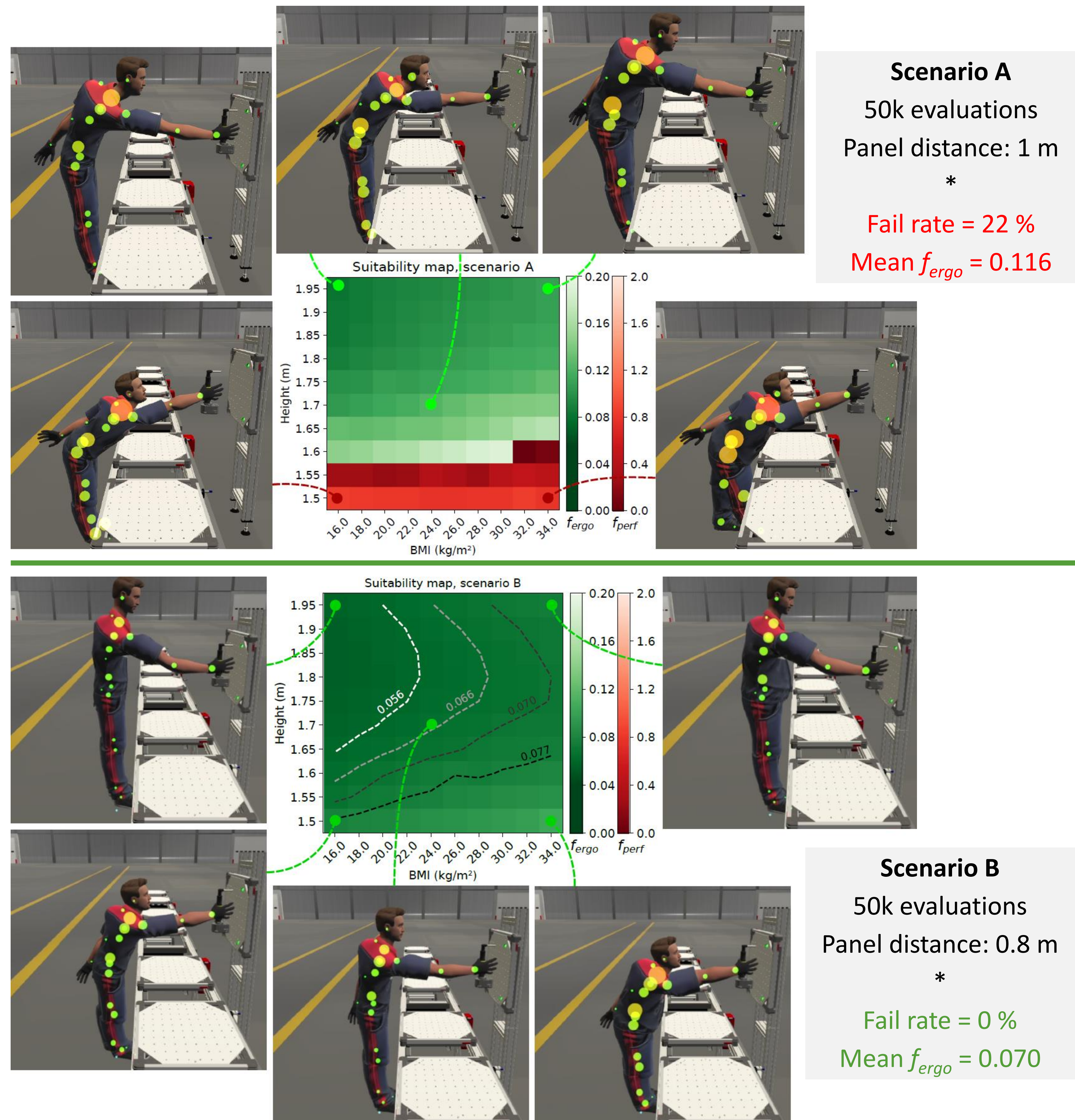
- Virtual workstation created with the XDE/XSM framework [1]
- Configurable DHM (47 DoFs) performing the activity
- Quadratic-programming (QP) controller based on the TSID library [2]

Behavioral adaptation with Multi-Task optimization:

- Intuition: similar morphologies have similar solutions
- Simultaneously optimize all morphologies with Multi-task MAP-Elites [3]



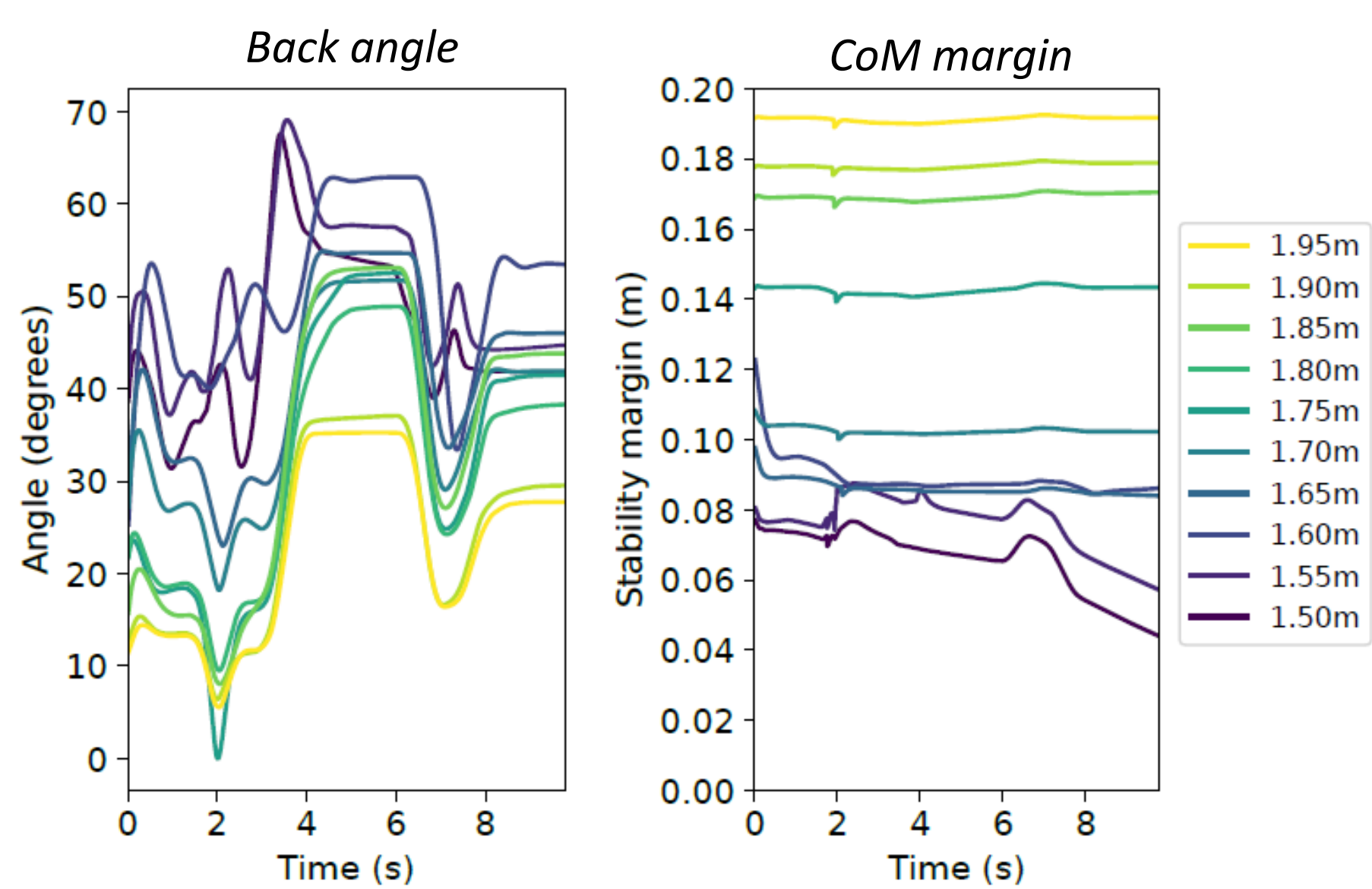
Suitability maps – Screwdriving activity



Behavioral strategies

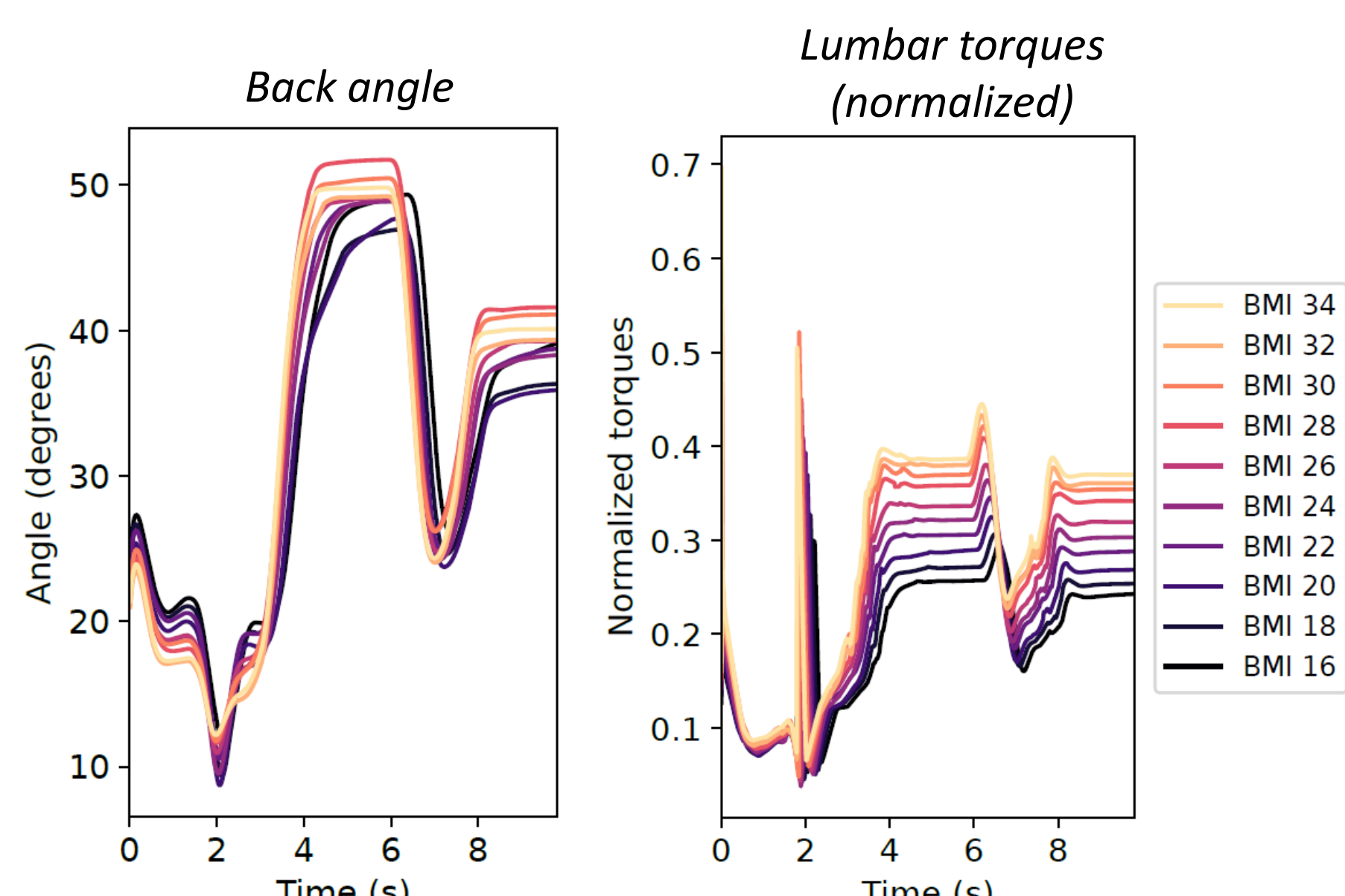
Effects of height
 (scenario A, BMI = 24)

- Smaller DHM need to lean forward more
- Smaller DHM have less stable postures

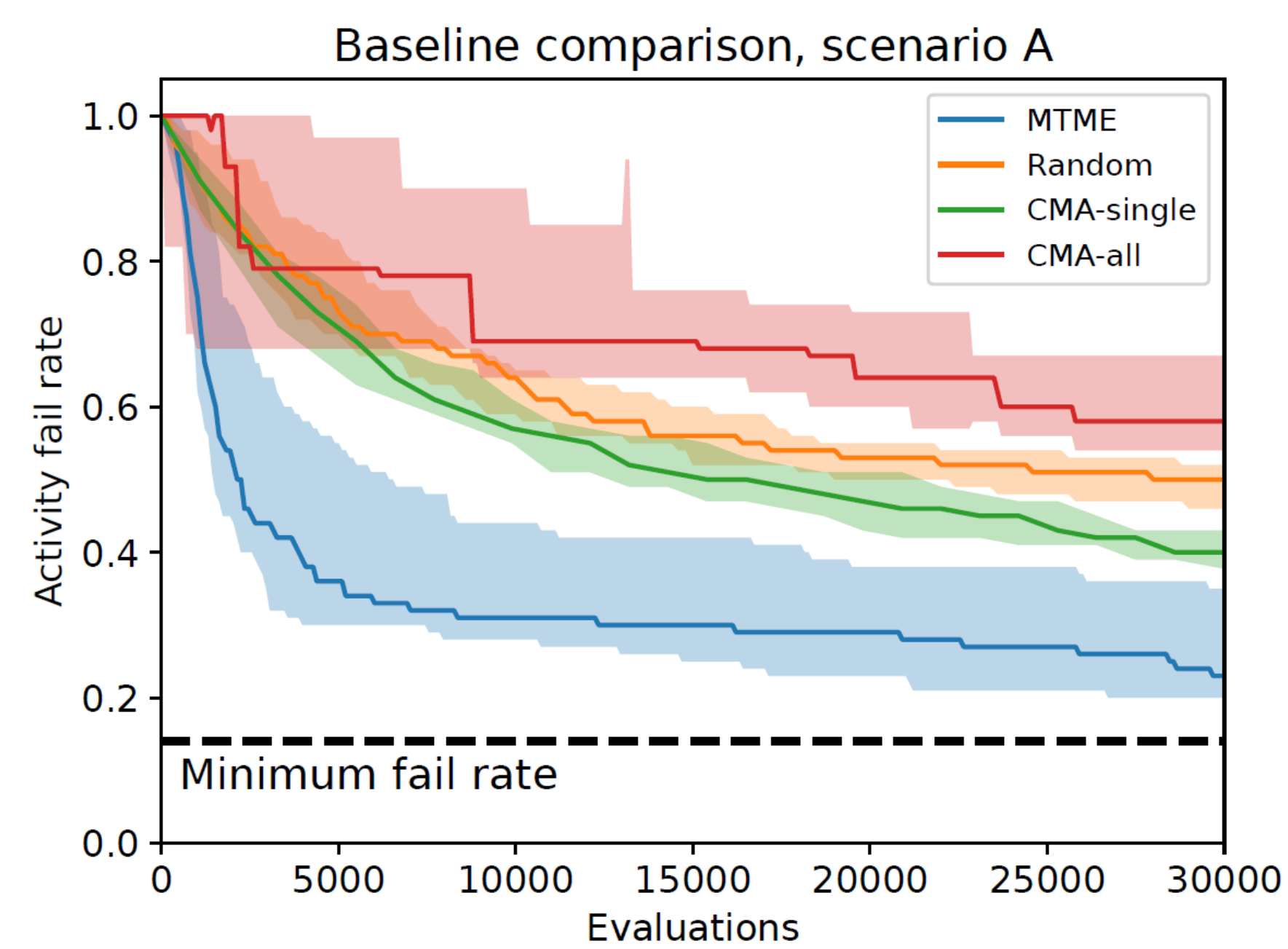


Effects of BMI
 (scenario A, H = 1.8m)

- Similar postures
- Higher BMI means higher torques on lumbar and lower body joints



Benchmarking



Baselines

- MTME:** Multi-task MAP-Elites
- Random:** Evaluate with random solutions and morphologies
- CMA-single:** Optimize each morphology separately with CMA-ES
- CMA-all:** Find one solution for all morphologies with CMA-ES

⇒ MTME outperforms all the other baselines.

Conclusion

With MTME, we were able to efficiently generate a large amount of morphology-adapted behaviors in order to assess workstation suitability.

Perspectives:

- Validate with an ergonomist on different scenarios
- Enrich the behaviors of the DHM: multi-contact, self-collision, ...
- Reduce computational cost

References

- [1] Merhlot, X. (2012) 'The XDE mechanical kernel: Efficient and robust simulation of multibody dynamics with intermittent nonsmooth contacts'
- [2] Del Prete, A. et al. (2016) 'Implementing Torque Control with High-Ratio Gear Boxes and Without Joint-Torque Sensors'
- [3] Mouret, J.-B. and Maguire, G. (2020) 'Quality diversity for multi-task optimization'