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

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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.

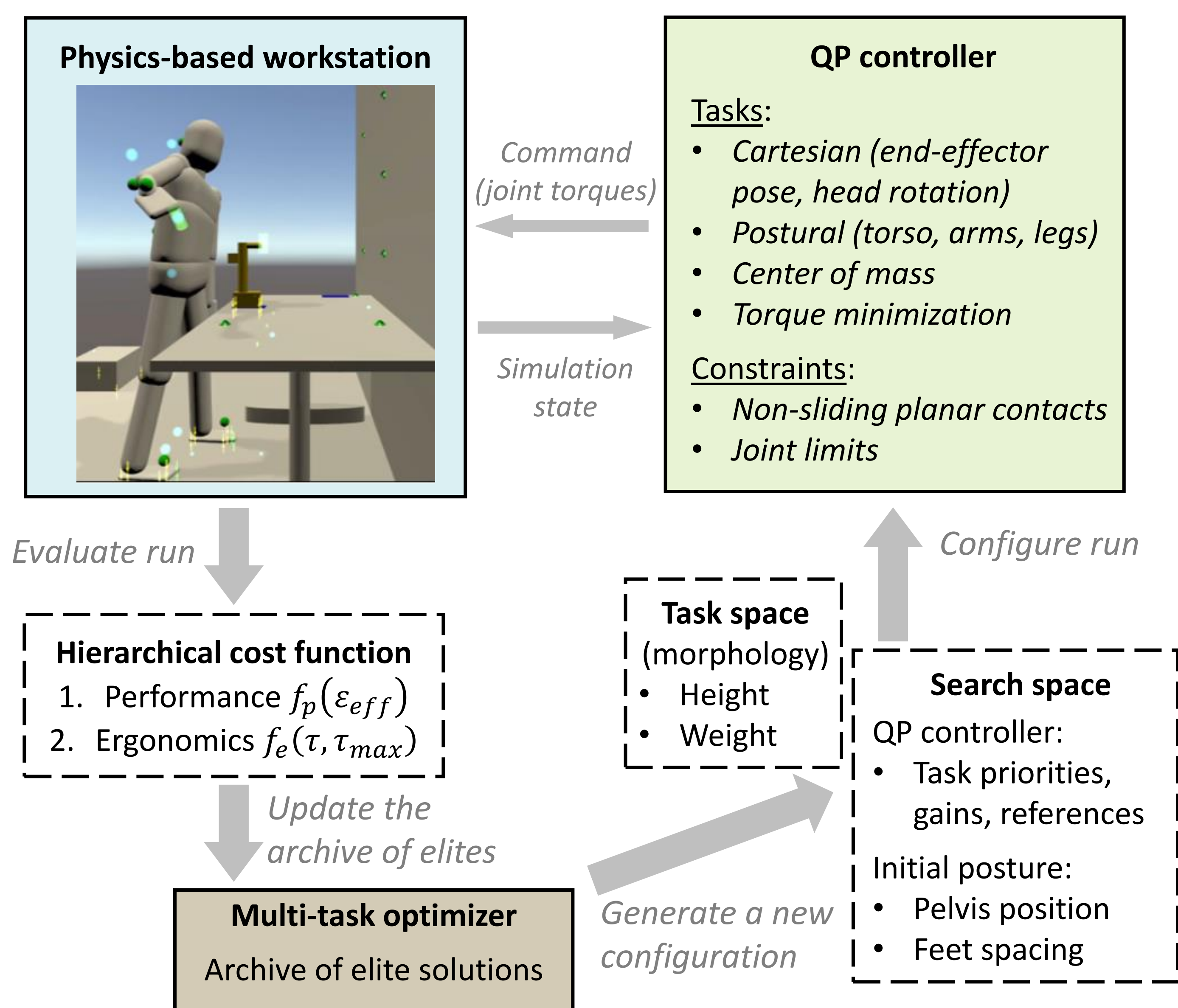
Method overview

Activity simulation with physics-based DHM:

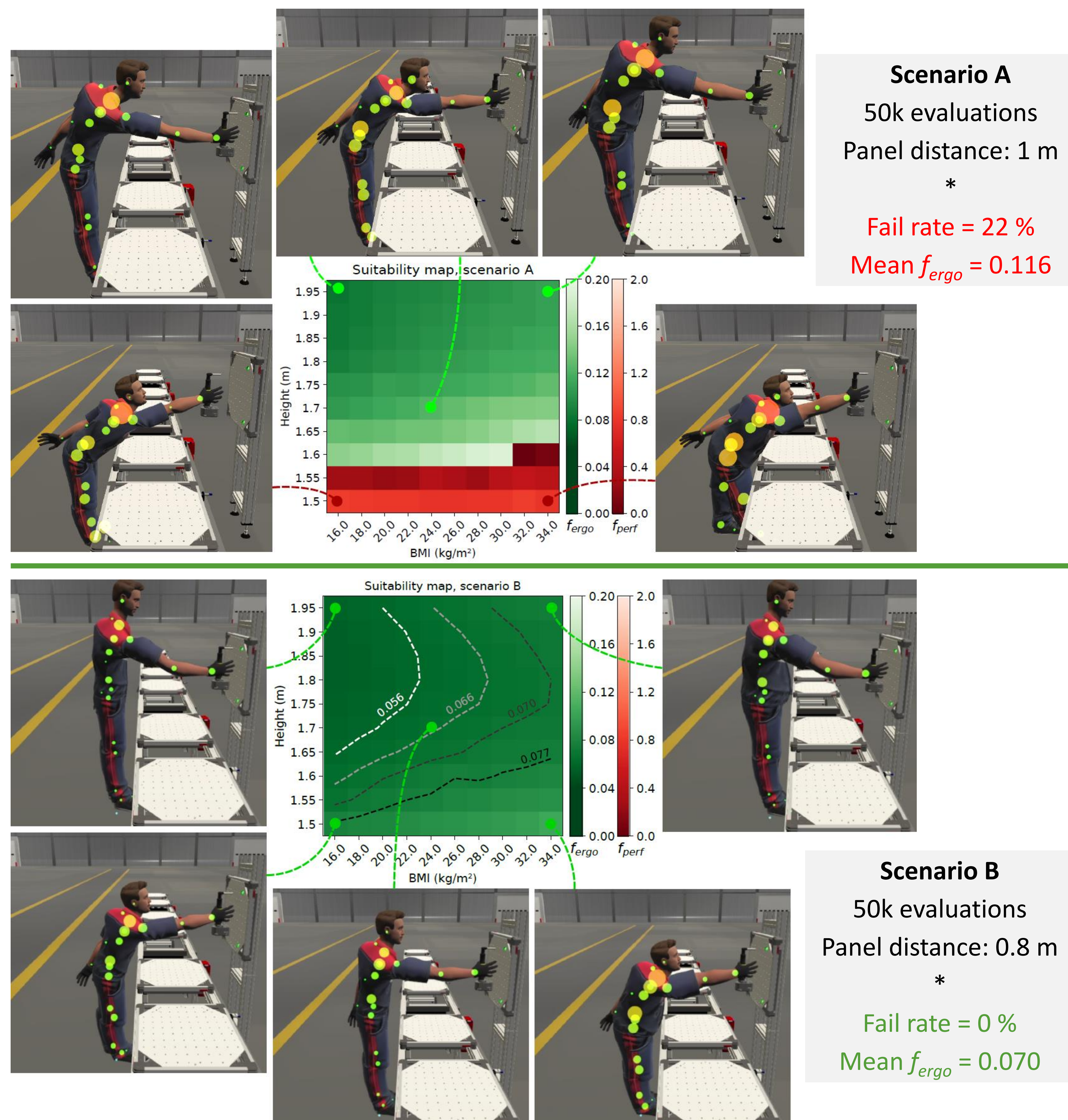
- Virtual workstation created with the XDE/XSM framework [1]
- Configurable DHM (47 DoFs) performing the activity
- Quadratic-programming (QP) controller based on the TSID library [2]

Behavioral adaptation with Multi-Task optimization:

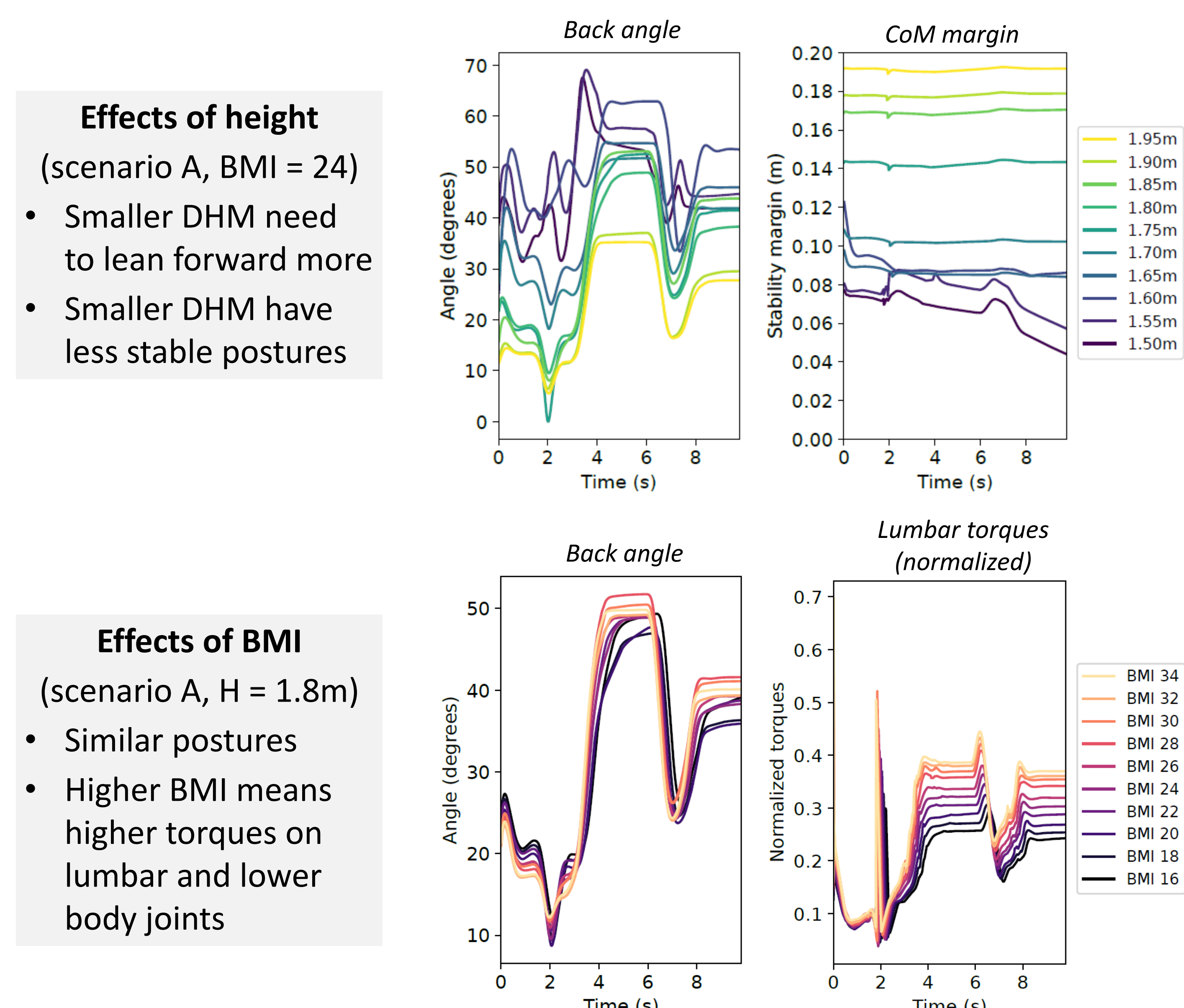
- Intuition: similar morphologies have similar solutions
- Simultaneously optimize all morphologies with Multi-task MAP-Elites [3]



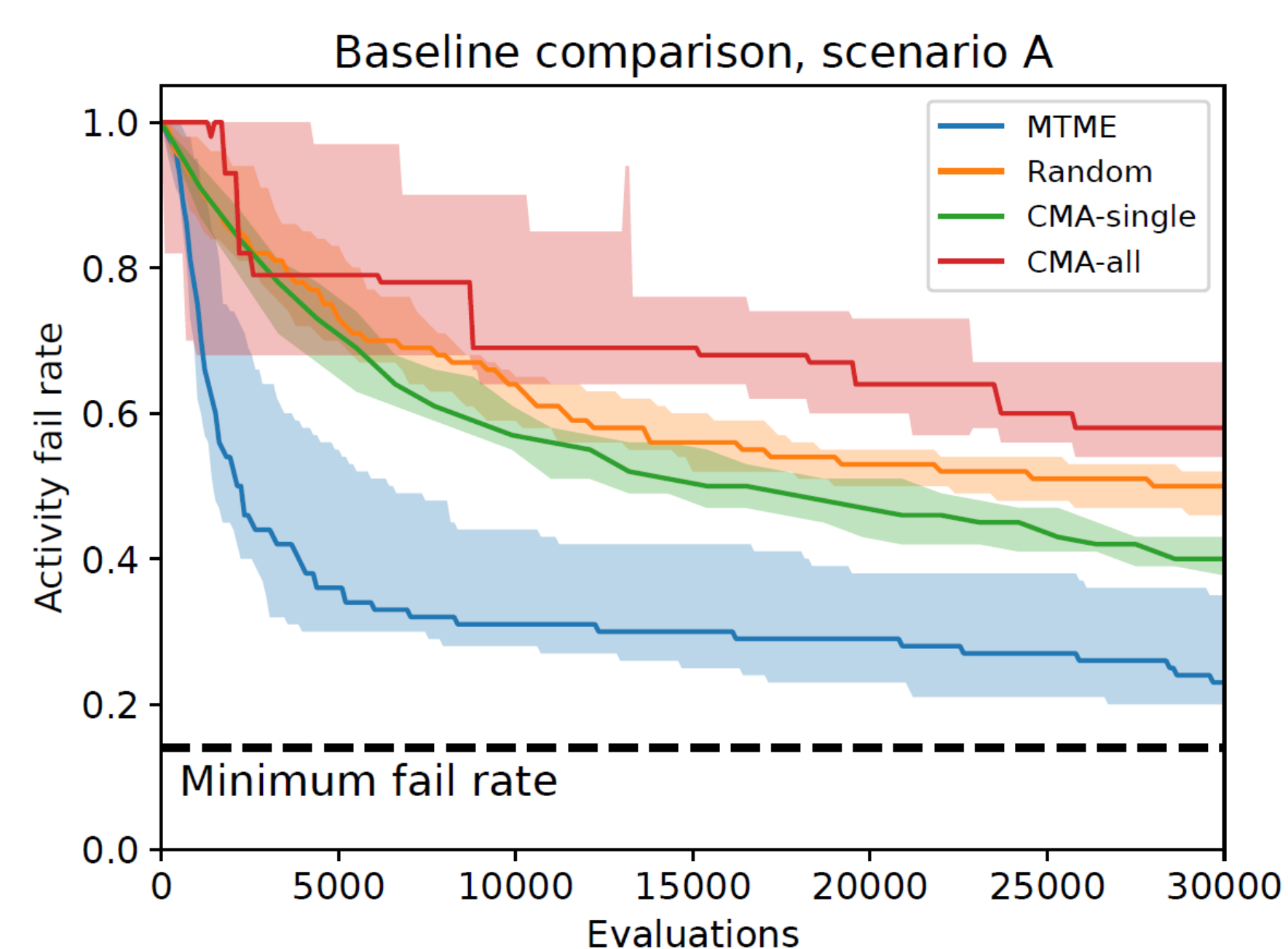
Suitability maps – Screwdriving activity



Behavioral strategies



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] Merhiot, 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'