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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

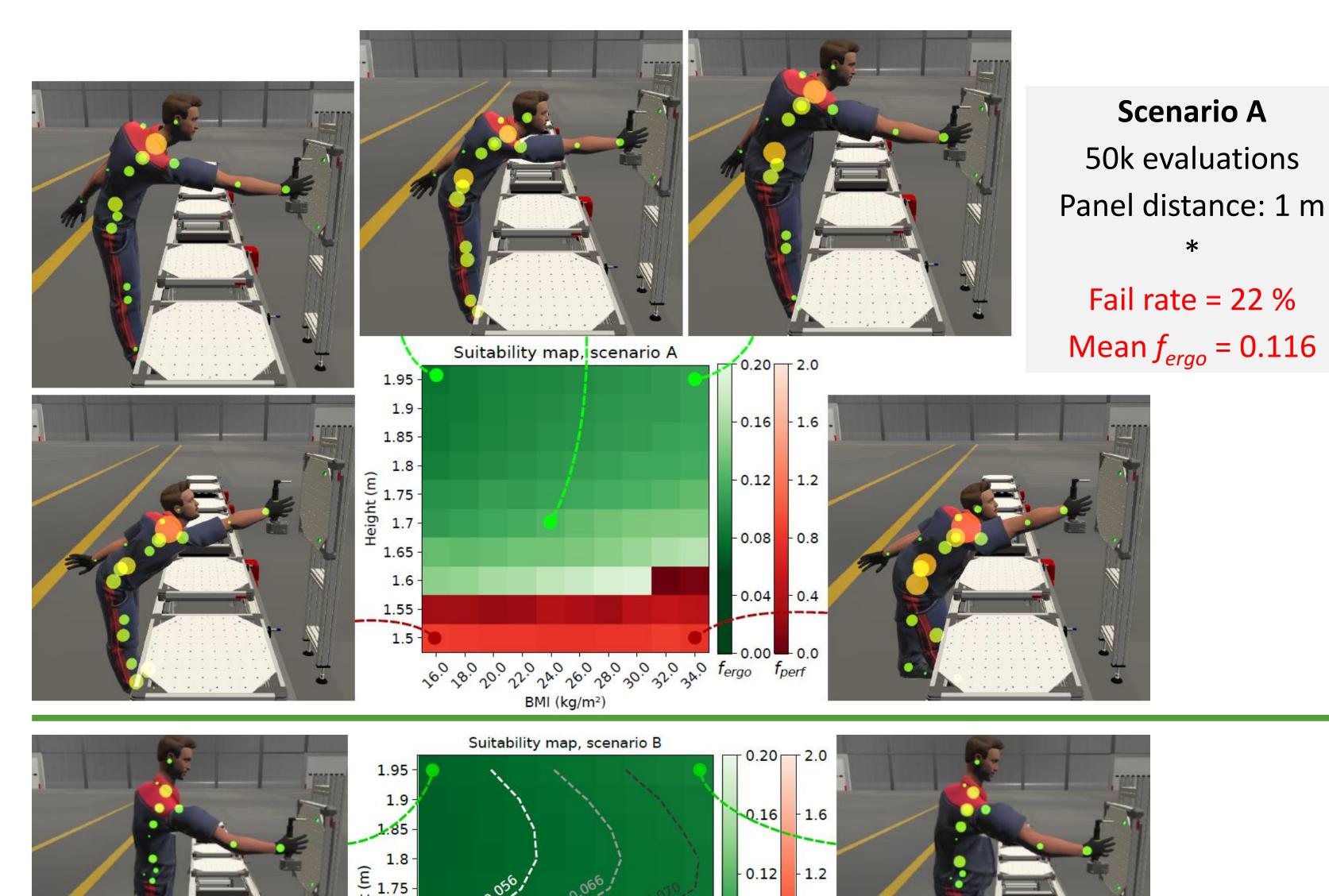
Compute workstation fitness maps over large populations of virtual workers,

by combining whole-body control and multi-task optimization.

Method overview

Activity simulation with physics-based DHM:

Suitability maps – Screwdriving activity



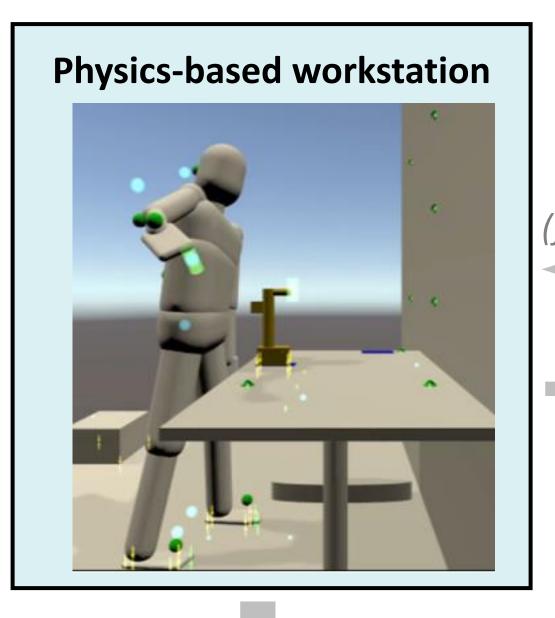
- Virtual workstation created with the XDE/XSM framework [1]
- Configurable DHM (47 DoFs) performing the activity
- Quadratic-programming (QP) controller based on the TSID library [2]

Behavioral adaptation with Multi-Task optimization:

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

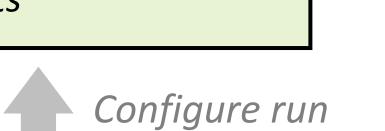
Command

state

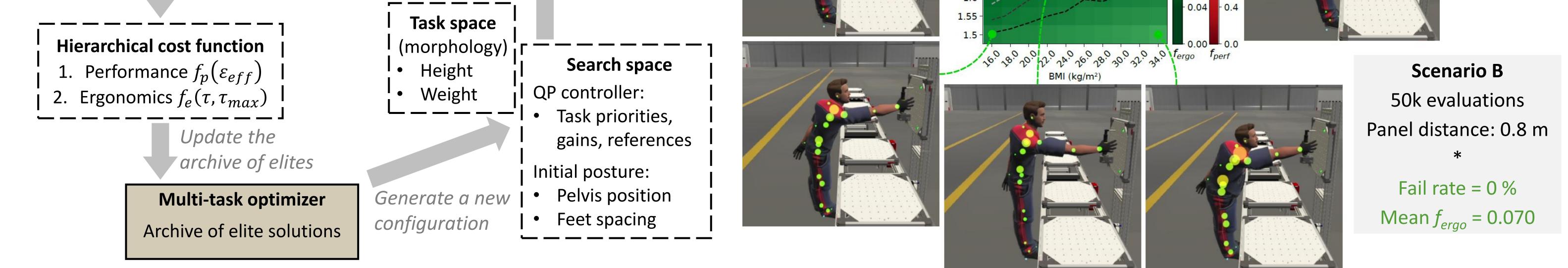


QP controller

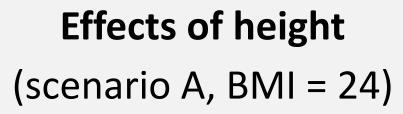
- <u>Tasks</u>: Cartesian (end-effector \bullet (joint torques) pose, head rotation)
 - Postural (torso, arms, legs)
 - Center of mass
 - Torque minimization
- Simulation Constraints:
 - Non-sliding planar contacts
 - Joint limits



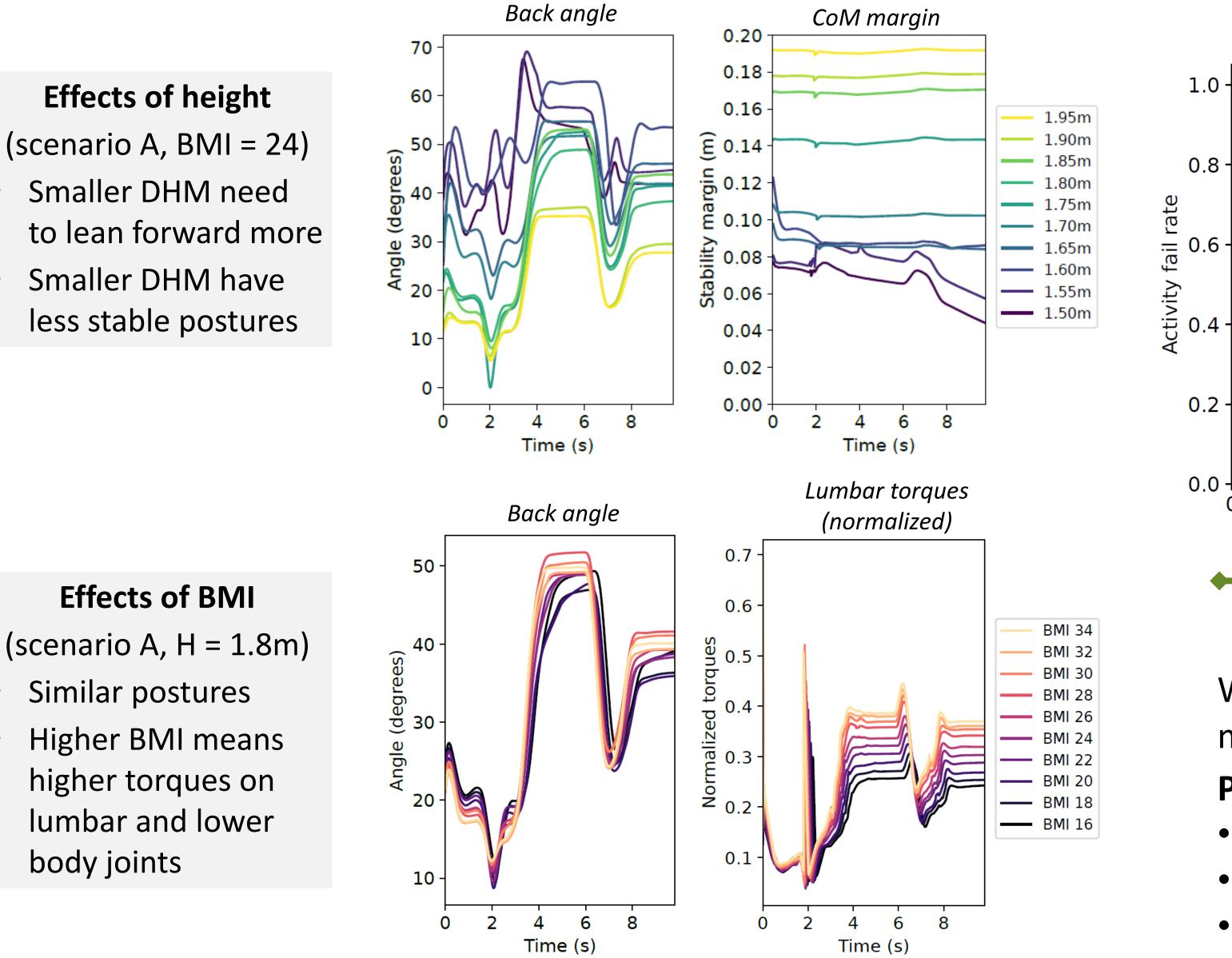
Evaluate run

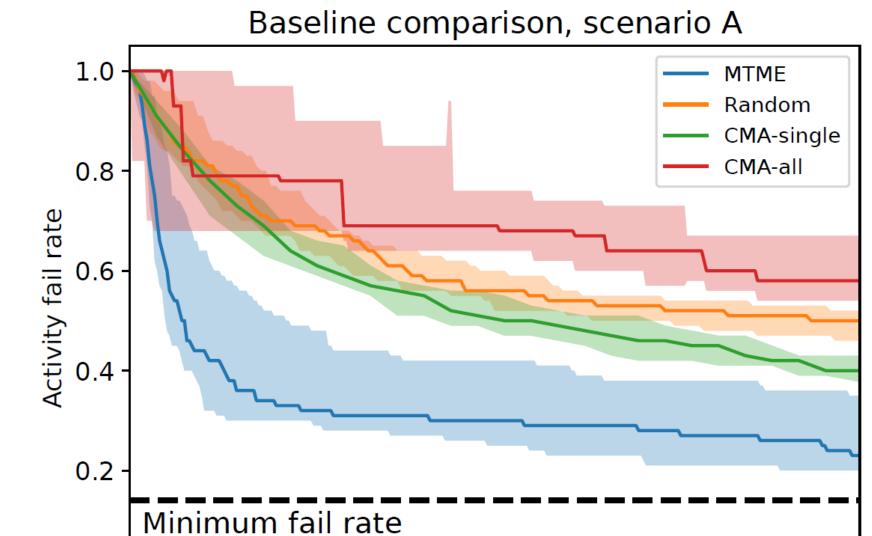


Behavioral strategies



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





1.65

Benchmarking

0.08 - 0.8

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

 \Rightarrow MTME outperforms all the other

baselines. 25000 30000 15000 20000 5000 10000 **Evaluations**

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 \bullet
- Enrich the behaviors of the DHM: multi-contact, self-collision, ...
- Reduce computational cost \bullet



References

- [1] Merlhiot, 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'