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► **To cite this version:**

Waldez Gomes, Pauline Maurice, Eloïse Dalin, Jean-Baptiste Mouret, Serena Ivaldi. Improving Ergonomics at Work with Personalized Multi-Objective Optimization of Human Movements. AHFE 2021 - 12th International Conference on Applied Human Factors and Ergonomics, Jul 2021, New York, United States. hal-03115203

HAL Id: hal-03115203

<https://hal.science/hal-03115203>

Submitted on 19 Jan 2021

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Improving Ergonomics at Work with Personalized Multi-Objective Optimization of Human Movements

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Objective

Provide a method to generate and optimize varied human movements for multiple ergonomic scores while respecting physics, as well as task and individual user constraints

Significance

Traditional ergonomic evaluation worksheets used in industry, such as RULA, REBA, or EAWS are very useful and efficient to evaluate a workstation, however, they should not be directly used as cost functions for movement optimization. The main issue is that they are mostly kinematic evaluations, whereas the dynamics have also a huge impact on joint efforts, exerted forces and equilibrium. All of these elements are critical in order to provide a personalized recommendation for an ergonomically optimal postural movement strategy. Moreover, user-specific constraints, such as disabilities and physical constraints must also be taken into account. Our solution enables optimization not only for user-specific constraints but also takes into account several ergonomics criteria at once. Because we use physically consistent simulation and control of a digital human model, we can easily generate varied motions while respecting physics, therefore, we can produce physically-consistent human movement optimization even if the human is physically interacting with a collaboration tool such as with robots or exoskeletons. Moreover, digital simulations allow for cheap, reliable, and repeatable evaluations of human movement in work environments.

**This work was supported by the European Unions Horizon 2020 Research and Innovation Programme under Grant Agreement No. 731540 (project AnDy) and from the European Research Council (ERC) under Grant Agreement No. 637972 (project ResiBots).

Methods

We propose a method to optimize user-specific movements with respect to different ergonomics criteria in a multi-objective fashion using personalized digital human models (DHM). The DHM can be easily parameterizable with any given user's morphology, directly from the user, as a digital twin, or from arbitrary body morphologies. Then, the DHM is simulated in a physical engine, similarly to a humanoid robot, with a whole-body multi-task quadratic programming controller that can prioritize for different elements of the DHM's motion as well as it can easily output several kinds of kinodynamical cost functions. On top of that, we use a multi-objective optimization process that enables us to find Pareto-optimal movement strategies that promote ergonomics criteria including kinematics and dynamics elements. We encode the human movements using probabilistic motion primitives (ProMPs) for taking into consideration several movement demonstrations at the same time, and compactly represent the trajectories in order to directly use them in non-linear classical optimizers. To validate our framework methods, we optimized an industry-inspired task for several different body morphologies, and additionally, used our framework to optimize an entire set of wholebody motions under several different, and complementary ergonomic scores.

Results and discussion

Our framework was able to show in several simulations that different body morphologies have different optimal movement strategies, even when executing the same work task, additionally, the optimal motions were also dependent on the used ergonomic score. Then, our multi-objective optimization provided movement strategies that would favor different ergonomic scores at the same time depending on the user preferences, and kinodynamical requirements. Our DHM simulation tool showed to be flexible and light, allowing for fast computing during demanding iterative processes such as non-linear optimizations.