A digital human tool for guiding the ergonomic design of collaborative robots

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The growing number of musculoskeletal disorders in industry could be addressed by the use of collaborative robots, which allow the joint manipulation of objects by both a robot and a person. Efficiently designing these robots requires to assess the ergonomic benefit they offer. Despite the advances in human biomechanics and virtual human simulation tools, the existing software for ergonomic analyses remain ill-adapted for collaborative robots design, because of the manikin animation techniques and the biomechanic criteria that are measured.

We present a generic tool for performing detailed ergonomic assessments of activities including collaborative robots. The proposed method relies on an evaluation carried out within a digital world, using a virtual manikin to simulate the worker. The evaluation of the robot-worker system can thus easily be performed throughout the whole design process.

Multiple ergonomic indicators are defined in order to exhaustively estimate the different biomechanical demands which occur during manual activities. In order to simplify their interpretation, a sensitivity analysis is conducted to extract relevant indicators which best summarize the overall ergonomic performance of the considered activity, as well as identify the robot parameters which mainly affect this performance. For this, multiple virtual human simulations of the activity - in which the manikin interacting with the collaborative robot is animated with an optimization-based whole-body controller - are run to measure all the ergonomic indicators for varying human and robot features. The relevant indicators resulting from this analysis can then be used to easily compare different robots, or to automatically optimize certain design parameters of a robot.

The whole method is applied to the optimization of a robot morphology for assisting a drilling gesture. The sensitivity analysis is performed on 28 ergonomic indicators with 8 different human and robot parameters, resulting in a total of 8000 simulations. This analysis enables to reduce the number of ergonomic indicators to consider in the optimization from 28 to only 3, hence facilitating the convergence of the optimization: robots performing well on all 3 ergonomic objectives are produced with an evolutionary algorithm in about 150 generations. The comparison of the situations without assistance and with near-optimal robots shows some lack of transparency in the robots, but a comparatively significant improvements in the force-related ergonomic indicators. This result demonstrates the benefit of the optimized robots and thereby confirms the relevance of the proposed approach to provide robot designers with interesting preliminary designs to be further worked on.

Keywords: Collaborative Robots, Ergonomics, Digital Human Simulation, Sensitivity Analysis