Modeling and Optimal Control of Human Lifting Motions

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Abstract:

Low-back pain is a common complaint in modern society and responsible for a large number of work absences that result in a huge economic burden on industry and healthcare. Spinal exoskeletons can reduce the risk of low-back injuries by supporting the back during physically demanding jobs, e.g. that require heavy lifting or staying in uncomfortable positions for a long time.

Designing such an exoskeleton is challenging because it must be applicable for various working environments. Technically speaking, it should support users during a diversity of lifting tasks, but should not restrict them during general motions like walking, sitting and stair climbing. A thorough testing of multiple prototypes is needed to guarantee that the exoskeleton satisfies these requirements.
Mathematical models of the human body and the exoskeleton combined with movement analysis or movement prediction can facilitate the design process: The prototype can be tested under various conditions and specific design requirements can be identified without it is even built.

In this work, we want to support the design process of a passive spinal exoskeleton by analyzing lifting motions and optimizing design properties, in particular spring stiffness values. For this purpose, we perform motion capture experiments with several subjects executing lifting motions with a 10kg heavy box. Based on recorded data and anthropometric measurements, we create subject-specific biomechanical models and models of passive spinal exoskeletons with springs attached to their joints.
The parameter optimization is set up as an optimal control problem: We compute dynamically consistent fits of the human models wearing the exoskeleton to the recorded lifting motions and the parameter values describing specific design properties of the exoskeleton (spring stiffness values) are variable and optimized during the fitting process. Additionally, we compute corresponding fits without the human models wearing the exoskeleton and compare both results for multiple subjects.

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