Data Driven Calibration and Model-based Backlash Compensation of Compact Series Elastic Actuators for Robotic Exoskeleton Gloves

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Abstract: Series elastic actuators (SEA) are widely used in wearable robotic systems and are identified as a good source of force or torque producing devices with low inertia for impedance control. The working principle of a SEA is based on using an elastic material connected serially to the mechanical power source to simulate the dynamic behavior of a human muscle. Due to weight and size limitations of a wearable robotic exoskeleton, the hardware design of the SEA is limited. Compact and lightweight SEAs usually have noisy signal output with backlash, and can easily be deformed. This research uses a compact lightweight SEA designed for robotic exoskeleton gloves that is able to compensate for backlash and account for immeasurable strain and friction force which can cause an average of 34.31% and maximum of 44.7% difference in force measurement on such SEAs. This research proposes a model-based backlash compensation method and two data driven machine learning methods to accurately calibrate and control SEAs. The multi-layer perception (MLP) method can reduce the average force measurement error to 10.18% and maximum error to 29.13%. The surface fitting method (SF) method can reduce the average force measurement error to 8.06% and maximum error to 35.72%. In control experiments, the weighted MLP method achieves an average of 0.21N force control difference, and the SF method achieves an average of 0.29N force control difference on the fingertips of the exoskeleton glove.

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