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Switching adaptive control of a bioassistive exoskeleton

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ABSTRACT

The effectiveness of existing control designs for bioassistive, exoskeletal devices, especially in highly uncertain working environments, depends on the degree of certainty associated with the overall system model. Of particular concern is the robustness of a control design to large-bandwidth exogenous disturbances, time delays in the sensor and actuator loops, and kinematic and inertial variability across the population of likely users. In this study, we propose an adaptive control framework for robotic exoskeletons that uses a low-pass filter structure in the feedback channel to decouple the estimation loop from the control loop. The design facilitates a significant increase in the rate of estimation and adaptation, without a corresponding loss of robustness. In particular, the control implementation is tolerant of time delays in the control loop and maintains clean control channels even in the presence of measurement noise. Tuning of the filter also allows for shaping the nominal response and enhancing the time-delay margin. Importantly, the proposed formulation is independent of detailed model information. The performance of the proposed architecture is demonstrated in simulation for two basic control scenarios, namely, (i) static positioning, for which the predefined desired joint motions are constant; and (ii) command following, where the desired motions are not known a priori and instead inferred using interaction measurements. We consider, in addition, an operating modality in which the control scheme switches between static positioning and command following to facilitate flexible integration of a human operator in the loop. Here, the transition from static positioning to command following is triggered when either the human–machine interaction force at the wrist or the end-effector velocity exceeds the corresponding critical value. The controller switches from command following back to static positioning when both the interaction force and the velocity fall below the corresponding thresholds. This strategy allows for smooth transition between two phases of operation and provides an alternative to an implementation relying on wearable electromyographic sensors.