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Optimal Sliding Mode Controller for Knee Flexion during Walking

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Abstract : This paper presents an optimal and robust sliding mode controller (SMC) to regulate the position of the knee joint angle for patients suffering from knee injuries. The controller imitates the role of active orthoses that produce the joint torques required to overcome gravity and loading forces and regain natural human movements. To this end, a mathematical model of the shank, the lower part of the leg, is derived first and then used for the control system design and computer simulations. The design of the controller is carried out in optimal and multi-objective settings. Four objectives are considered: minimization of the control effort and tracking error; and maximization of the control signal smoothness and closed-loop system's speed of response. Optimal solutions in terms of the Pareto set and its image, the Pareto front, are obtained. The results show that there are trade-offs among the design objectives and many optimal solutions from which the decision-maker can choose to implement. Also, computer simulations conducted at different points from the Pareto set and assuming knee squat movement demonstrate competing relationships among the design goals. In addition, the proposed control algorithm shows robustness in tracking a standard gait signal when accounting for uncertainty in the shank's parameters.

Keywords : optimal control, multi-objective optimization, sliding mode control, wearable knee exoskeletons
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