

Extremum Seeking Control for Model-Free Auto-Tuning of Powered Prosthetic legs

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I. BACKGROUND

State of art powered prostheses are often controlled using a collection of impedance controllers designed for different phases of a gait cycle. Consequently, finite state machines are needed to govern transitions among different phases of each gait cycle. This approach requires a large number of impedance parameters and switching rules to be tuned. Since one set of control parameters cannot be used across different amputees, clinicians spend enormous time tuning these parameters for each patient. Recent work on powered prostheses control has employed approaches such as rule-based fuzzy logic inference [1] and adaptive dynamic programming [2], to name a few, in order to find an optimum set of impedance controller parameters for the knee joint. These approaches, however, have two main limitations: (i) they cannot tune control parameters of multiple joints simultaneously; and (ii) they have not demonstrated the ability to learn the control parameters across different subject/model physical attributes.

II. PROPOSED APPROACH

This talk proposes a virtual constraint-based control scheme with a smaller set of control parameters, which are automatically tuned in real-time using an extremum seeking control (ESC)-based scheme [3]. ESC, being a model-free control method, assumes no *a priori* knowledge of either the powered prosthesis or human. These advantageous factors make ESC a suitable candidate for automatic tuning of powered prosthetic leg control system parameters, with a minimal need for clinicians' intervention.

The proposed ESC-based automatic tuning of powered prostheses controller parameters was validated in simulations [4] and tested on a real powered prosthetic leg, UTD Leg-1, shown in Fig. 1. Both the bench-top and able-bodied experiments demonstrated successful adaptation of the PD controller parameters used for enforcing the virtual constraints. In this talk, we will present preliminary experimental results of online PD gain adaptation using ESC that are implemented on Leg-1. The adaptation rate of the PD control parameters was, however, slow because of the need for time scale separation between the Leg-1 dynamics and the ESC dither signal frequency. In order to address the slow adaptation problem, it might be possible to employ the periodic walking signals, which are generated by the human-powered prosthetic leg dynamic system, as the dither signals (see Fig. 2). Using the state-dependent dither signals, which contain information about the rate of the rhythmic task under control, it might be possible to eliminate the need for

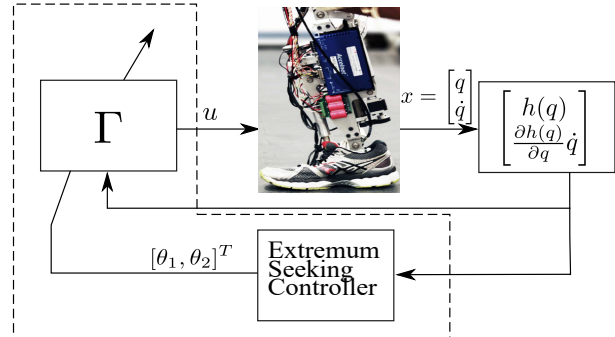


Fig. 1. Block diagram of the proposed ESC-based scheme. The controller Γ represents a PD controller, whose gains are being automatically tuned by ESC. The PD control and ESC together enforce the virtual constraint $y = h(q)$.

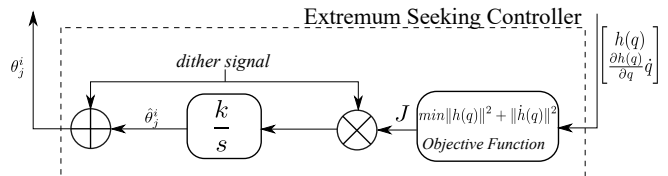


Fig. 2. Perturbation based ESC

having time-scale separation, resulting in a slow parameter adaptation. Future work will also involve optimization of multiple conflicting objective functions such as amputee comfort level and tracking error, where extremum-seeking will be used for multi-objective optimization [5].

Acknowledgments: This material is based upon work supported by the National Science Foundation under Grant No. 1728057.

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