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Adaptive Control of an Upper Extremity Rehabilitation Robot with Backlash

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Extended Abstract

In Canada over 40,000 new stroke cases are reported annually [1], and it costs the Canadian health care system $3.2 billion a year [2]. Thus, new rehabilitation technologies are being investigated. A rehabilitation robot can be used to deliver repetitive practice to the stroke patients, which is the key element for motor recovery [3, 4]. Safety issues regarding human-robot interactions restrict selection of control scenarios. Currently admittance and impedance control approaches and their variations are used to control the rehabilitation robots [5]. To implement these control strategies, a complete and accurate dynamic model of the robotic system is required. This issue can be addressed by incorporating robust or adaptive control approaches in the above strategies. For the robust control, if the dynamic uncertainties of the robot are too great, the quality of adaptive assistance or resistance may be compromised during therapy [6]. In the adaptive control, for the convergence of the adaption law, a persistently exciting input is required [6], but this will adversely affect the patient's motivation for using the device. In addition, both adaptive and robust controllers may need high gains when mechanical discontinuities (such as gear backlash) are introduced to the system dynamics. Hence, a precise dynamic model estimation is essential, and can be done through a proper system parameter identification approach.

A modified homotopy parameter identification [7] of the robotic system can be used to find the unknown system parameters. However, backlash parameters (i.e. left and right clearances) can be altered by the user input, since they are estimated when there is no human-robot interaction. This will adversely affect the computed torque through incorrect kinematics imposed by the user input. Therefore, in this study we propose a model reference adaptive controller to estimate the updated values of the left and right clearances of the backlash, and compensate the kinematic changes caused by the user input. Since the convergence of the estimated parameters is not pursued, persistently exciting input is not required. We implemented our method on an upper extremity rehabilitation robot, which has been designed and developed by Quanser Inc. and the Toronto Rehabilitation Institute (TRI). The robot is a belt-driven two degree-of-freedom parallelogram arm which moves the hand in the horizontal plane to perform reaching movements for therapy. Robot dynamics are discontinuous because of the gear-belt backlash. For running experiments, we locked one of the joints of the robot and simplified the robot to a single link with a joint drive backlash. Then a modified adaption law derived from [8] was used to update the backlash parameters. As a part of future work, the adaptive controller will be used to control the whole robot, and the system performance will be evaluated.

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