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Human Dynamic Behavior-based Gravity Compensation of a Rehabilitation Robot for Continuous Passive Motion

Aufa Chehlah, Paramin Neranon* and Nattha Jindapetch

Prince of Songkla University, Faculty of Engineering, HatYai, Songkla 90110, Thailand

* Corresponding Author: E-mail: paramin.n@psu.ac.th

Abstract. Regarding upper-limb rehabilitation, several research groups have developed robotic continuous passive motion devices to provide the improvement of physical functions of patient's muscles. Traditionally, once a robotic passive movement is applied to a patient's joint, and if he/she feels any restriction or pain, the subject can directly inform a therapist to reduce a range of motion or deactivate the machine. However, the reaction time delay of the human could significantly bring more the risk of harm or serious injury to the patient. To solve the problem, a one-DOF upper-limb rehabilitation robot based on circular path movement, which can be automatically compliant to the human resistant force applied, has been developed. After carefully analyzing the system based on traditional mass-based gravity compensation, we found errors of the force reading system occurred while measuring the (tangential) resistance force exerted by the human. Consequently, this paper highlights human dynamic behavior-based gravity compensation of the rehabilitation device to overcome the problem. The results show that the newly proposed gravity compensation technique can be used effectively in the force measuring system of forearm flexion/extension-based CPM therapy. By comparing the RMS errors of the new model to those of the traditional mass-based gravity compensation technique, the percent reduction of the RMSE is approximately 6.04-14.70% representing the decrease of the system errors in all cases. Hence, the human behavior-based gravity compensation will be further implemented on the autonomous upper-limb rehabilitation robot, which is suggested as future work.

Keywords: Continuous passive motion, Gravity compensation, Human dynamic behavior, Human forearm resistance force, Curve fitting