CONTROL SYSTEM DESIGN FOR A WRIST AND FOREARM REHABILITATIVE DEVICE

According to the World's Health Organization[1], 15 million people per year suffer from stroke globally, and 5 million become permanently disabled as a consequence of such complications. Moreover, by increase in the geriatric population, as well as the invention of effective therapies for acute stroke management, more stroke-survivors tend to live with the resulting disabilities. Damages from stroke, due to physical, cognitive, psychological, emotional and socio-economic consequences, severely affect patients' life and also their families'. To maximize the quality of life for stroke survivors, therefore, efforts to prevent disabilities must be prioritized, along with stroke prevention initiatives. Hence, the demand for stroke rehabilitation is increasing dramatically. Rehabilitation robots have been verified clinically to be effective in terms of long duration and consistent rehabilitation therapies needed for relearning sensorimotor after neurological injury.

Coordinated hand and wrist therapy, to improve the performance of activities of daily living, has gained traction recently. To this end, diverse control strategies has emerged for rehabilitating stroke patients with respect to the existing constraints and level of impairment. This study is dedicated to design and simulate a control system for a formerly developed 3-DOF hand and forearm rehabilitative device so that this device would be suitable for training and rehabilitating the impaired arm, relearning sensorimotor relationships and improving functional performance. In this study, patient's comfort during the therapy and the quality of interaction between the patient and the device (HRI) are the main concerns.

As the first subtask, kinematic and dynamic modelling for the device are extracted, utilizing Denavit–Hartenberg method and Newton-Euler approach respectively. High repetition number is considered a key factor contributing to a successful therapy in educating the patient on sensorimotor skills. To apply the effective common strategy of assistive rehabilitation, the patient is required to move the paretic limb, i.e. hand in this device, in a specified path from an initial to a final assigned posture, and frequently repeat this task. To do so, motion control is applied by designing an inverse dynamics controller in joint space. It was simulated in Simulink by two blocks and a subsystem which represents the device in interaction with the hand. The first block generates trajectories with trapezoidal velocity profile. The second block, controller block, by getting desired and real trajectories, computes the torque command for the robot, through ID control approach. Next block, is a subsystem which models the device in interaction with the patient's hand. In this case, the hand acts as the environment in which the grip force is exerted to the manipulator's end-effector. To compute the grip force, the data of a clinical study carried out by Dr. Burssens, et al. is used.

The main focus in rehabilitative systems is to assist the patient in completing the desired tasks to improve the paretic limb's strength and motor control; hence, accuracy in the control system can be compromised, prioritizing patient's comfort. Therefore, flexibility was regarded as one of the prominent factors in designing this control system, which was achieved by reducing the rigidity of the system.

To evaluate the designed system, joint position error, joint velocity error, and torque command graphs were considered. The designed system, ultimately, reached a reasonable accuracy and the simulated interaction between the patient and the device got qualified enough so that it would be suitable to be implemented on the device. Afterwards, OpenSim was used to solve the inverse dynamic problem for the modeled hand in order to determine the generalized forces at each hand joint. These forces provide physiotherapists with a criterion to figure out the level of involvement for each hand joints during the designed therapy. To do so, the computed torque of the manipulator's end-effector was extracted from the Simulink to OpenSim.

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