**ICMIEE20-KN11**

# Design and Control of Upper Extremity Rehabilitation Robots

*M. H. Rahman, Brahim Brahmi, Tanvir Ahmed, Asif Al Zubayer Swapnil*
Department of Mechanical Engineering, University of Wisconsin Milwaukee, WI, **USA**

**ABSTRACT**

Functional impairments of the Upper and/or Lower Extremities (ULE) are common not only among the elderly, but also can occur after a stroke. The World Health Organization reports that stroke affects each year more than 15 million people worldwide. In the US alone, more than 795,000 US people suffer a stroke each year that results in significant deficits in ULE functions and the performance of everyday tasks for those affected. The problem is further compounded by the constantly growing number of such cases. It is estimated that about two-thirds of the stroke survivors incur acute arm impairment. Therefore, one of the challenging aspects of stroke rehabilitation is upper extremity intervention. There is mounting evidence that functional recovery can occur well into the chronic stages of stroke. Late improvements may be attributable to sensorimotor learning and adaptive plasticity in the remaining cortical and subcortical brain tissue. On the other hand, the literature review reveals that the aged population also significantly loses arm and hand function. Thus, there is a pressing need to develop better treatment/therapeutic approaches to decrease the effects of disability due to stroke/geriatric disorders.

The current standard for treatment of upper extremity dysfunctions resulting from a stroke/geriatric disorders is personalized therapy with an OT (involves a large time commitment on the part of the OT, and the treatment duration is very long). Unfortunately, there is a consistent shortage of qualified therapists/clinicians both in developing and developed countries. Therefore, an alternative to conventional treatments/interventions is essential. Past research has shown that intensive movement therapy of the affected extremity, incorporating functional tasks where feedback is provided may lead to improved functions. These key elements of motor learning need to be integrated in rehabilitation paradigms and this can be accomplished through rehabilitation robotics.

To rehabilitate individuals with upper-limb dysfunctions, we have developed end-effector type and exoskeleton type therapeutic robots. The exoskeleton type robot, named Smart Robotic *Ex*oskeleton (SREx) is comprised of a shoulder motion support part, an elbow and forearm motion support part, and a wrist motion support part. It is designed to be worn on the lateral side of the upper limb in order to provide naturalistic movements of the shoulder (i.e., vertical and horizontal flexion/extension, and internal/external rotation), elbow (i.e., flexion/extension), forearm (i.e., pronation/supination), and wrist joint (i.e., radial/ulnar deviation, and flexion/extension). Our end-effector type robot, named Intelligent Therapeutic Robot (iTRob, V.1), composed of 2DoF specially designed for the individuals who are not able to use exoskeleton robot.

The SREx was modeled based on the upper-limb biomechanics; it has a relatively low weight, an excellent power/weight ratio, can be easily fitted or removed, and is able to effectively compensate for gravity. The exoskeleton was designed for use by typical adults, whereas the iTRob was designed for use by children, adults, and/or elderly individuals. The kinematic models of the robots were developed based on modified Denavit-Hartenberg notations, and Newton-Euler formulation was used in dynamic modeling. The control architecture was implemented on a field-programmable gate array (FPGA) in conjunction with a real-time PC. Nonlinear control techniques (model-based and adaptive controller) were used to maneuver the robots to provide active and passive arm movement therapy.

In experiments, typical rehabilitation exercises for single and multi-joint movements (e.g., reaching) were performed. Experimental results show that the developed therapeutic robots can effectively perform passive and active rehabilitation exercises for shoulder, elbow, and wrist joint movements.

**Keywords:** Exoskeleton Robot, End-effector type Robot, Upper-Limb Dysfunctions, Rehabilitation, Nonlinear controls.