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A NEW MASTER-SLAVE CONTROL METHOD FOR IMPLEMENTING FORCE SENSING AND ENERGY RECYCLING IN A BILATERAL ARM TRAINING ROBOT

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Abstract. *Recently, bilateral arm training has attracted great attention in the development of rehabilitation robots to provide therapy for hemiplegic patients with a unilaterally disabled limb. It has been proved that bilateral arm exercise can stimulate ipsilateral corticospinal pathways and enhance recovery; also the coordination of the two limbs can reduce hypertonia and abnormal synergies compared to unilateral limb training. In conventional bilateral arm training robots, the healthy limb provides a reference movement and the robot gives an assistant force for the impaired limb to implement mirror image movements, or the healthy limb assists the impaired limb to accomplish the desired movement, whereas no resistant force was supplied for patients with the healthy limb to perform strength enhancement training. This paper introduces a novel master- slave rehabilitation robot to implement bilateral arm coordinated training. The robot supports passive, active-assisted, and active-constrained training modes. No matter in which mode, the corresponding force provided for the impaired limb is from the healthy limb. A prototype was developed with two identical motors. A subject controls the two motors with his/her two limbs to accomplish desired movements. Preliminary tests were conducted, the results confirm the validity of the system in different training modes, and verify the system's force sensing capability, energy recycling function, and bidirectional controllability.*
Keywords: Bilateral arm training, Force sensing, Bidirectional control, Master-slave motion tracking, Energy recycling

1. **Introduction.** Nowadays, the increasing number of hemiplegic patients with a unilaterally disabled limb and the shortage of physical therapy resources have imposed a heavy economic burden on patients and society. Hence, numerous robots have been developed to deliver arm therapy, such as the systems introduced in literatures [1-4]. In addition, some novel control strategies were proposed for rehabilitation robots [5,6]. It has been verified that robotic therapy systems can provide effective treatment.

In order to carry out rehabilitation training for patients with different residual motor capacity, the robots that have been developed [7-10] usually support different training modes, including: a passive mode with the severely impaired limb being trained passively; an active-assisted mode with the robot providing an auxiliary force to complete the movements initiated by the mildly impaired limb; and an assisted-constrained mode with the robot exerting a resistant force to hinder movements controlled by the impaired limb with certain recovered motor function (strength enhancement training). Recently, the development of rehabilitation robots supporting bilateral arm training is a new trend. The representative device is MIME [11-14], which assisted the affected limb to move with the same manner of motion as the contra-lateral limb, with the two limbs performing bilateral