Chapter 1

Emerging Technologies for Neuro-Rehabilitation after Stroke:
Robotic Exoskeletons and Active FES-Assisted Therapy

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ABSTRACT

Rehabilitation of motor function has been linked to motor learning that occurs during repetitive, frequent, and intensive training. Neuro-rehabilitation is based on the assumption that motor learning principles can be applied to motor recovery after injury, and that training can lead to permanent improvements in motor function in patients with motor deficits. The emergent research field of Rehabilitation Engineering may provide promised technologies for neuro-rehabilitation therapies, exploiting the motor learning and neural plasticity concepts. Among those promising technologies are robotic exoskeletons and active FES-assisted systems, which could provide repetitive training-based therapies and have been developed to aid or control the upper and lower limb movements in response to user's intentionality. This chapter describes those emerging technologies to enhance the neuro-rehabilitation processes of motor-disabled people at upper limb level and presents how a natural control to command above external devices from Electromyography could be implemented.

INTRODUCTION

Stroke is a leading cause of disability in most of countries around the world, affecting people with motor deficits that limit their ability to execute activities of daily living (ADL). Impairments may involve loss of motor, sensory and/or cognitive functions. Specialized rehabilitation programs may provide functional motor recovery. Rehabilitation of motor function has been linked to motor learning that occurs during repetitive, frequent and intensive training. This sensorimotor activity base

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on neural plasticity, which is the ability of health areas of the brain to reorganize and compensate for lost function in other brain regions (Moller, 2006). The human neuromuscular system exhibits use-dependent plasticity, which means that use modifies the properties of neurons and muscles, their connectivity, and thus their function.

Neurorehabilitation is a process that explores neural plasticity in order to assist people in recovering motor ability (Dietz, Nef & Rymer, 2012). Much of neurorehabilitation rests on the assumption that patients can improve with practice through motor learning. Repetitive motor activity in a real-world environment with a cognitive effort has been identified in several studies as favorable for motor recovery in stroke patients (Moller, 2006). For effective neurorehabilitation processes, it is required to analyze and determine the patient needs in order to design a customized training and rehabilitation program taking into account that each patient has specific requirements for rehabilitation and training. Thus, it is imperative to enhance the patient's potentials with technological or medical devices which have to be highly adaptive and configurable, characteristics exhibits by emerging technologies as Robotic Exoskeletons and active FES-assisted systems. The former are biomechatronic human-centered devices externally coupled to the person, i.e. a "wearable" robot (Pons, 2008). The capacity of applying dynamic forces to the body and specifically to upper and lower limb opens the application field of robotic exoskeletons for neurorehabilitation; the latter are systems that use Functional Electrical Stimulation (FES) to generate a specific motor function in response to user´s intention (Doucet, Lamb & Griffin, 2012). FES refers to electrical stimulation of muscles in order to improve the impaired motor function. This is achieved by activating skeletal muscles with constant frequency trains of stimulations.

In order to implement a natural control to command external devices such as robotic exoskeletons or active FES-assisted systems, a relevant source of commands can be extracted from Surface Electromyography (SEMG). SEMG signal reflects the muscular force level, and consequently the intention for movement. Thus, they can be used as input information for control in external systems. Physically impaired people may use surface SEMG signals to control in an automatic way, rehabilitation or assisting devices. Implementation of the EMG-based control is not easy to be accomplished due to some difficulties, among them that EMG signals are time-varying and highly nonlinear.

This chapter presents the role and application of robotic exoskeletons and active FES-assisted therapies for neurorehabilitation processes. Furthermore, it is presented computational methods involved in myoelectric control of robotic exoskeletons to be used in nerurorehabilitation applications.

BACKGROUND CONCEPTS IN NEUROREHABILITATION AND MOTOR RECOVERY

Several processes have been identified as playing a role in neurological recovery following stroke; however, the role each plays is not completely understood. Scientific researches have indicated that the cerebral cortex undergoes functional and structural reorganization for weeks to months following injury with compensatory changes. Recovery can be grouped into two categories: 1) local CNS processes (early recovery); 2) CNS reorganization (later recovery) (Sharma, Classen & Cohen, 2013). Neurological reorganization plays an important role in the restoration of function. It can extend for a much longer period of time than local processes, and is of particular interest because it can be influenced by rehabilitation training exploiting the motor learning concept.

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