Chapter 3
Active Assistive Orthotic System:
(Exoskeleton) Enhancing Movement

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ABSTRACT
Active orthosis (exoskeleton) is an assistive device with a wearable structure, corresponding to the natural motions of the human. This chapter focuses on developing an active/assistive orthosis system (AOS) enhancing movement. The AOS design is inspired by the biological musculoskeletal system of human upper and lower limbs and mimics the muscle-tendon-ligament structure. The exoskeleton structure includes left and right upper limb, left and right lower limb, and central exoskeleton structure for human torso and waist and provides support, balance, and control of different segments of the body. The device was fabricated with light materials and powered by pneumatic artificial muscles that provide more than fifteen degrees of freedom for the different joints. The active orthotic systems (AOS) can operate in three modes: motion tracking system with data exchange with virtual reality; haptic and rehabilitation device; and assistive mode with active orthosis in cases of impaired muscles.

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INTRODUCTION

An exoskeleton is wearable robotic device with joints and limbs corresponding to those in the human body. The exoskeleton transmits torques to human joints by actuators and has four basic functions according to the control algorithms (Perry J., Rosen J, Burns S., 2007):

1. **Rehabilitation**: The exoskeleton fits closely to the body and fulfills tasks of physical therapy in an active or passive working mode (Tsagarakis and Caldwell, 2003, Gupta and O’Malley, 2006, Perry J. et al., 2007, Rahman M.H. et al., 2010);
2. **Master Device**: For “master-slave” tele-communication robot control. The interaction forces are applied to the slave exoskeleton by moving the master (Nakai et al., 1998);
3. **Auxiliary Device**: Human body amplifier that supports body weight so as to minimize the loading on the joint. The operator feels the loads accepted by the exoskeleton lighter (Lee, S. et al., 1998)
4. **Haptic Device**: The subject physically interacts with virtual objects. The interaction forces are applied by the exoskeleton actuators. It should be noted that the haptic exoskeletons found application in rehabilitation as well.

Many upper limb exoskeletons with different mechanical structure and actuation, with or without force feedback haptic devices, have been presented in the literature. The first exoskeleton arm for replication of sensations of contacts and collisions was designed by Perceptual Robotics Laboratory (Bergamasco M. et al., 1994). This is a seven degree of freedom ungrounded device, attached to operator’s shoulder and torso. The operator holds onto the device with his/her palm. Hence, the device can only exert forces at the palm of the user. It uses DC motors with a cable transmissions. This haptic device was designed to the purpose of a more fully immersive simulation. The authors from PERCRO have developed another arm exoskeletons for haptic interaction with virtual environments L-Exos (Frisoli A. et al., 2005; Frisoli A. et al., 2007; Frisoli A. et al., 2009). This is a five-DoF exoskeleton with a wearable structure and anthropomorphic workspace. Another active exoskeleton as kinesthetic force/moment feedback device with 6 DoF is known as Freflex (Wright-Patterson) exoskeleton (Williams et al., 1998). A7 DoF arm type haptic interface for teleoperation and virtual reality systems was designed by university of Tokyo (Nakai et al., 1998). The newly redesigned exoskeleton presented of (Sledd Alan et al., 2006) is capable of providing kinesthetic feedback to the joints of the lower arm and wrist of the operator, it is used for robot-assisted rehabilitation and training.

A 9-DoF under-actuated exoskeleton arm using pneumatic actuators is developed by (Lee, S. et al., 1998). Their device allows full reproduction of the human arm’s workspace by the exoskeleton. An alternate arm exoskeleton developed at the Korea Institute of Science and Technology addresses the limited wearability issues of previous designs by using parallel mechanisms and pneumatic actuators (Jeong Y. et al., 2001). However, this solution have the disadvantage of requiring an auxiliary system, limiting the possibilities of displacement of the exoskeleton. Interface-envelope MGA, of the University of Georgetown, is able to provide several superiors human capabilities (Carignan et al., 2005) indicated to the shoulder and elbow, while the MAHI of the University of Rice is oriented to the rehabilitation of the forearm (Gupta and O’Malley, 2006). Other examples of dedicated exoskeletons primarily a rehabilitation are Armin from the University of Zurich (Nef et al., 2007) and the LDCs the University of Salford which uses pneumatic actuators (Tsagarakis & Caldwell, 2003). The wearable Salford arm addresses some of the issues and limitations of earlier designs (Tsagarakis, N.G., Tsachouridis, V., &