Development and Control of Hand Exoskeleton System Using Intended Movement

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Abstract

Hand motor impairment is a common disability among stroke survivors that severely affect their ability in activities of daily livings (ADLs), reducing independence and quality of life. Throughout the rehabilitation process, stroke patients able to regain partially or fully the hand motor function. However, the conventional rehabilitation process is limited by the insufficient number of therapists, labor-intensiveness, and low compliance. The objective of this study was to support the rehabilitation process and ADLs through the development of the Flexible Linkage Hand Exoskeleton Rehabilitation Robot (FLEXOR), a five fingers 3D printed prototype actuated by linear actuators. FLEXOR was controlled using intended movement to support the independent exercises and to assist the ADLs movement. An Arduino-based control system driven by electromyography (EMG) signal was developed for FLEXOR. The new control system protected the hand against over-flexing and excessive application of force. The control system was programmed into three different operating modes which enable FLEXOR to provide passive exercises to the fingers, assist fingers in ADLs movement with minimal efforts, and provide active exercises while assisting fingers in ADLs.

Keywords: hand exoskeleton, rehabilitation, control system, Arduino, electromyography

Introduction

Stroke is the third-largest cause of death in the world. Hand motor impairment is a common disability among stroke survivor and affect their ability to perform activities of daily living (ADLs). Throughout rehabilitation process, stroke patients regain partially/fully motor hand function. However, conventional rehabilitation process is limited by insufficient number of therapists, labor-intensiveness, and low compliance. To overcome the limitations, several robot hand exoskeletons had been developed for rehabilitation purpose [1–3]. Robot hand exoskeleton improves the rehabilitation process by delivering high-intensity and frequency training without requiring full-time monitoring by a therapist and expected to increase the recovery pace.

Reference [1] developed a robotic hand based on master-slave motion mode. The robotic hand consists of rigid exoskeleton and glove (flexible wearable type) to improve the 'mirror therapy'. By using the glove on the healthy fingers, the movement of the affected fingers is controlled by using the rigid exoskeleton. The movement of the healthy fingers drives the affected fingers to perform consistent movement using somatosensory interaction technology. Reference [2] developed an EMG-driven robotic hand that consisted of five linear actuators and provided individual mechanical assistance of the five fingers. The proximal and distal sections of the index, middle-, ring-, and little finger were rotated around the virtual centers located at the metacarpophalangeal (MCP) and proximal interphalangeal (PIP).

The robotic hand was also applied as an assistive device to support the elderly and disabled people including the stroke/post-stroke patient to perform the ADLs and improve the quality of life (QOL) such in [4–8]. For example, Ref. [4] developed a portable and compact robot hand to help post-stroke patients to perform ADLs. The focus was on the size, weight, motion profile, and mechanism of movement. The novelty was lied in a unique cable-driven mechanism using dual linear actuators to perform the index and middle fingers flexion and used adjustable flexible rubber for finger extension. There was a similarity in the development process of robot hands for rehabilitation and assistive purposes although there was an argument that the rehabilitation-based robot hand only operated in controlled medical settings [4]. In general, both developments focused on either mechanism, control system, sensory, interface, and so on.

However, a system that allows patients to perform exercises by themselves and assist them in ADLs is needed to make rehabilitation more accessible and affordable, producing better outcomes and ultimately improve the post-stroke QOL of the patient. Such requirements are fulfilled by a robotic hand exoskeleton with the capability to analyze, sense, and monitor patient motion, allowing the patient to control the robotic hand exoskeleton. Rehabilitation training protocol that is adjusted by therapists is replicated accurately to ensure consistent outcomes. Moreover, the robotic hand exoskeleton compensates for the patients' weakened strength to improve their independence in ADLs during their long process of recovery. In response to the above requirements, Flexible Linkage Hand Exoskeleton Rehabilitation Robot (FLEXOR), as shown in Fig. 1, had been developed as a rehabilitation and assistive device for stroke patients. In this paper, the development and control system of the robot hand is discussed, and the initial results are presented.

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