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System integration and control of finger orthosis for post stroke rehabilitation

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Abstract

Stroke is a major cause of long-term disability among adults in many countries. Post stroke rehabilitation consumes a huge amount of health care resources in terms of costs related to hospital and home assistance. Recently, robot-assisted rehabilitation has been introduced to support physiotherapists in providing high-intensity and repetitive rehabilitation sessions. It has been observed that robotics offers an objective and reliable tool to monitor patient's progress and to accurately assess their motor function. This paper presents a novel finger rehabilitation approach for acute paralyzed stroke survivors using a wearable device for hand motor function restoration. After analyzing four main working mechanisms for hand assistance and rehabilitation, i.e. pneumatic cylinders, artificial rubber muscles, linkage mechanism and cable-driven mechanism, a new device called Pneumatic Actuated Finger Exoskeleton (PAFEx) has been designed. The prototype development was carried out in four stages involving simulation of the assisted structure of the MCP joint and the PIP joint, algorithm development, design and fabrication of prototype as well as product function evaluation. Offering ease of use and affordability, the device has great potential to be deployed for individualized rehabilitation session for patients who have to undergo therapy in their home.

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Keywords: Acute stroke; prevention contracture; finger rehabilitation; flexion; extension; exoskeleton

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1. Introduction

Stroke is one of the third largest causes of death in the world behind cancer and heart diseases [1]. There are many stages in stroke and our main focus is on the acute patient, which is to perform passive range of motion to prevent muscle contractures [2]. In many countries, finger disabilities and injuries are mostly caused by stroke. A healthy finger is an important aspect in human daily life. However, abnormal condition such as disabilities, injuries, deformation and diseases of the hand, can impact human activities of daily living (ADL).

One of the approaches in solving the finger disabilities and injuries is doing the finger rehabilitation [3]. The finger rehabilitation is physiotherapy approaches which aim to partially or entirely recover the finger motor function of the patient [4]. The physiotherapy approach is based on how to manipulate the paretic limb which supported by a physiotherapist [5]. The approach may be accomplished with daily rehabilitation frequency for up to several months, depending on the severity of the finger and the condition of the patient [6]. In order to be recovered to a normal life, the patient needs time and consistent doing the rehabilitation assisted by the physiotherapist [7]. However, since the number of the physiotherapist is limited, it will not be easy for the patient to do the rehabilitation which needs to be supported by the physiotherapist all the time [8].

The objective of this project is to develop an exoskeleton that can assist the finger rehabilitation exercises. Due to the limited numbers of physiotherapist, there is a need to develop a rehabilitation system where the patients can carry out rehabilitation exercises on their own. This project however is a pilot study in order to enhance research on the finger rehabilitation. The project starts with a mechanical design of exoskeleton for an index finger. The main idea of the design is to perform an extension and flexion of the finger based on mechanisms that can transmit the force from the actuators.

Hence, we were investigated to develop and fabricate a new type of robust hand and finger rehabilitation device which can control human hand to do flexion and extension motion. Our hypothesis by enforcing the correct flexion and extension motion, it can help patients with hand and fingers muscles problem to close hand and open hand correctly and improve healing. Most of hand and finger device for rehabilitation available on the market uses the passive control system. Unfortunately, the active control systems are costly and need a bigger space to install, not portable and not suitable to use at home. Therefore, the current study for the first time attempts to produce a robust, low cost device employing active control system using pneumatic air cylinder. In this paper will discuss on the development process of the design concept, simulation and the fabrication of the device. The initial prototype of the device is also included. Since the exoskeleton only performs a flexion and extension thru the mechanism, the modification of the exoskeleton will be conducted in order to qualify as an index finger rehabilitation device. Later sections will detail out the workflow of this project.

2. Methodology

The methodology that involved in developing and fabricating a new type of robust hand and finger rehabilitation device can be summarized into four (4) sections: Simulation of the assisted structure of MCP (Metacarpophalangeal) joint and PIP (Proximal Interphalangeal) joint, Control Algorithm Development, Orthosis Design Development and Fabrication, and System Evaluation.

At the initial stage, we finalized the orthosis design with an index finger and thumb finger based on the mechanics of human hand anatomy. Most of the finger rehabilitation device nowadays focuses on the stroke patient [9]. However, the practical usage of the finger rehabilitation can be extended to help the elderly and disabled people. This can be done by providing the elderly or disabled people with a device that can increase the power of the grasping [10]. Therefore, the main idea of this project is to develop a device that can be used for a wide range of end user not only for grasping purpose but also for the extension motion of the finger.

Since fingers are the main focus of the project, the analysis of the mechanics of human hand anatomy is the starting point in the exoskeleton development stage [11]. The understanding of the human hand anatomy is essential since it can help the developer to emphasis in which part of the finger is involved in the motion [12]. Besides that, the literature review of previous works also needs to be done to provide an outline of this area.