Chapter 1

Design and Implementation of a Smart Mechatronic Elbow Brace

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ABSTRACT

This project develops a design and implementation of a smart mechatronic brace used as a rehabilitation device for elbow injury patients training their bone ligaments and muscles, and recovering at home. The proposed brace is designed to be low cost and to fit large different users since it is able to be regulated and combined with reliable mechanical and electronic parts, and to correspond to high safety requirements. Electromyography (EMG) sensors are used above the skin to measure the biopotential signals from the muscles to detect the human motion intention, and then, to recognize the flexion/extension movement. Data of the human motion intention and direction are processed and converted into the pulse-width modulation signals (PWM) to run DC motors. A prototype for this brace is fabricated and tested with real human motion intentions and directions. The DC motors can follow well the human motions with the error of less than 7^0 *over a moving angle of* 120^0*.*

DOI: 10.4018/978-1-7998-0137-5.ch001

INTRODUCTION

Elbow injuries are prevelant. According to recent statistics, about 80% of injuries are related to the damages of human activity system and half of them are on the upper limbs or the elbow injuries (Smania, Berto, Melotti, & Miditi, 2012). Due to the complexity of the human neuromuscular system, the postoperative recovery may take 12-24 months. And it is important to maintain the stiffness of the joints and avoid motion limitations, muscular contractures, and the development of secondary deformities. Therefore, it is needed mechatronic devices integrated with updated technologies for upper limb rehabilitations.

The main purpose of rehabilitation period is to return normal mobility for the injured joints via physical exercises with trained therapists. In bio-mechanics, many smart devices are emerging to replace expensive training sections with therapists as they allow the patients training at home. This project develops a home-based rehabilitation orthosis for the elbow injured patients with low cost, high accuracy and integration with modern technologies.

The main movements occurring at the elbow joint are flexion, extension, pronation and supination. The range of elbow motion is from 0° to approximately 145° in the normal person. Flexion here is due to the action of biceps, brachialis and brachioradialis muscles. Extension is achieved from the action of the triceps muscle located in the posterior aspect of the arm. The biomechanics of the elbow joint are affected by the bones, muscles and ligaments. Weakness in muscle or injury to ligaments can result in abnormal forces in the elbow, which can ultimately over time cause degeneration of the articular cartilage of bone (Shahid, Fletcher, Robati, & Pemmaraju, 2015).

The passive devices or the mechanical braces containing with meatal and rubber bands are simple, safe and low cost. But after some periods of time, they lose the rehabilitation properties. And the patients must come to the clinic to replace them. Therefore nowadays, there are many active devices for longtime home-based treatment.

Active devices provide active motion assistance via their mechatronic system. Such assistance is supporting patients, who are too weak to perform physical exercises. There is a wide range of such active devices on market and namely mechatronic wearable orthoses.

A review of modern active elbow orthoses with short description and disadvantages is shown in table 1.

The mechatronic systems from these active elbow orthoses are used to deliver power to joint and manipulate movements of the elbow. So, they must be high precious and have enough power to provide adequate torques. There are many types of actuators for these devices, such as electric, hydraulic, pneumatic, pneumatic artificial muscles, series elastic actuator and inverse pneumatic artificial muscles. The review of modern actuators and their transmission system is presented in table 2.

In order to obtain the appropriate human intention signal for the actuation system, sensors and control system are installed based on six sources of (1) Brain activity – EEG, MEG, (2) Muscle activation – EMG, (3) Muscle contraction – MK, MT, (4) Body segment movement – IMU, (5) Joint rotation – Goniometer, and (6) Force/Pressure deformation. The review of sensors and control system is shown in table 3.

According to tables from 1 to 3, all orthoses have disadvantages in mechanical design. Most of the devices have motor placed only on one side which leads to undesired torsion. Further, most of orthoses are built with quite heavy and expensive components. Their weight exceeds 2.5 kg and the cost exceeds $1000.

In order to follow the joint movements, the human intention signal must be measured and translated to PWM to run the motor. EMG sensors and subsequent signal processing subsystems are always the best solution. Based on the EMG signals, the user intention motion can be identified from the estima-

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