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Improved Design Approach on Rehabilitative Exoskeleton

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Abstract
The following paper reviews the research and development towards an exoskeleton that not only help patients suffering from partial paralysis regain their upper limb movement but also help the people that don't get enough or any physical therapy get a certain amount of therapy by using the system. The system can also be used in daily life as a means of power assist for regular people.

I. Introduction

An exoskeleton is a system that has been designed to provide augmentation power to ordinary individuals as well as to assist physically weaker individuals in regaining their strength. An exoskeleton is employed to denote the outward of the skeleton of an inborn, which fulfills the protagonists of safeguard, identifying, and support [1]. The recompenses of its rigidity and protective characteristics are subsequently emulated and utilized by humans to create shield suits, orthotics, and prosthetics. Conferring to Nef et al. [2]. The idea of this research paper is to develop a system that helps patients suffering from transverse myelitis, motor dysfunction and many other types of disease which causes partial paralysis or help patients that need physical therapy due to an accident that caused motor dysfunction, regain complete movement in their upper limbs using exoskeleton. [14]

II. Upper limb Muscular system

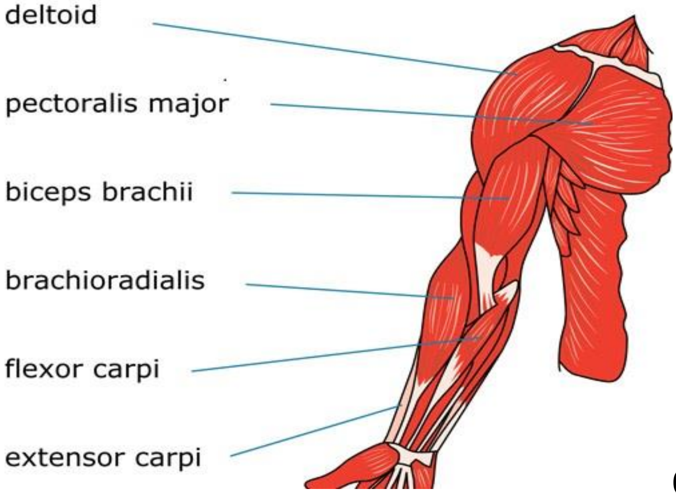
A. **The Biceps** muscle is situated on the anterior side of the upper arm. At its proximal end, it is divided into two portions (heads), separately having its particular ligament. The short head originates from the coracoid process of the scapula and extends in front of the shoulder joint towards the arm. The long head originates from the margin of the glenoid cavity, and its tendon passes through the joint cavity and the bicipital groove to reach the arm. It functions to stabilize and flex the shoulder joint, and at the elbow joint, it aids in flexion and supination. (Fig 1)

B. **Triceps** muscle is situated on the posterior facet of the humerus. It functions to extend the elbow joint. (Fig 1)

C. **The Brachialis** muscle is located on the anterior aspect of the upper arm, positioned deep to the biceps, and serves as the primary flexor of the elbow joint. (Fig 1)

D. **Deltoid muscle** fibers originate from the clavicle, acromion process and spine of scapula and radiate over the shoulder joint to be inserted into the deltoid tuberosity of the humerus. (Fig 1)

E. **Pectoralis major** lies on the anterior thoracic wall. The fibers originate from the middle third of the clavicle and from the sternum and are inserted into the lip of the bicipital groove of the humerus. It draws the arm forward and towards the body, i.e., flexes and adducts. (Fig 1)

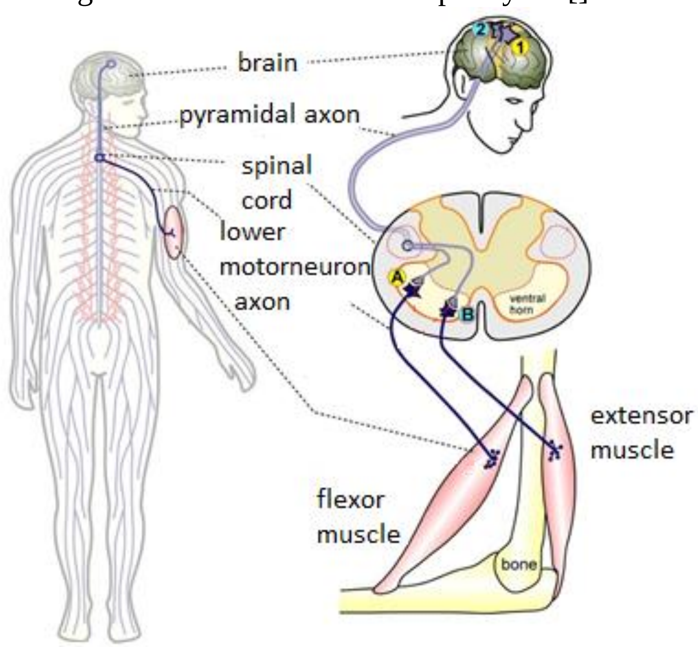


(Figure 1: Upper limb Muscular system)

III. Electrical signals in a human arm

Like muscle fibers, neurons possess the property of electrical excitability. They interact with one another through two distinct types of electrical signals, which facilitate communication over both short and long distances within the body. The generation of these signals is contingent upon two fundamental characteristics of the plasma membrane of excitable cells and the existence of specific ion channels.

Various nerve compulsions are diffused from the brain to the figure over bales of nerve fibers within the spinal cord. The motor paths extending from the brain to the muscles consist of two neurons. The electrical signals present in the nerves are responsible for enabling arm movement. Damage to these nerves results in paralysis. []



(Figure 2: Electrical signals in the human arm)

IV. Paralysis

Paralysis refers to the loss or reduction of motor function in a specific area as a consequence of the severance of the neural or muscular mechanism, along with the loss of sensory function. Paralysis can be extensive in nature. It may manifest on one side or both sides of the body. It may also be localized to a single part. The majority of paralysis is caused by impacts or injuries such as spinal cord trauma or a damaged neck.

V. Rehabilitation

According to Caldwell et al. [3], there are additional (700,000) individuals in the United States and over (65,000) individuals in the United Kingdom who survive a stroke annually. Resulting from a stroke, Monoplegia and Hemiplegia are forms of paralysis that require physical therapy to restore the patient's motor functions. But due to non-life threating and labor-intensive programs, little or no physical therapy is given to these patients [4], this further complicates the condition of these patients. In order to help these patients this research is focused on developing an exoskeleton to allow patients receive physical therapy from the comfort of their home.

VI. Power Assist

Exoskeleton can not only be used for helping patients regain their motor movement but it can also help in power augmentation, burden reducing and muscle training. An exoskeleton can also be rummage-sale to increase the power of fighter in directive to transmit dense weapons, gears, and apparatus. [5] Lately, some effective yields of powered exoskeleton were presented such as Berkeley Exoskeleton (BLEEX), Sarcos Exoskeleton and MIT Exoskeleton [6].

VII. Comparison

In the 1890's the first so-called exoskeleton was produced by a Russian scientist named Nicholas Yagn's. This exoskeleton used airbags and bow springs for augmented power.

In 1965 the Hardiman exoskeleton was developed. The idea was to create a suit that a user can wear and gain augmented powers. The problems were the suit was too heavy and slow to be able to use because the electrohydraulic servos were slow. But the main factor of its demise was that the suit was divided into two parts, upper limb extremity, and lower limb extremity, the scientist could not attain the balance that was required to use the exoskeleton. [9]

In the early 2000's The Bionics Lab at UCLA developed an exoskeleton which was focused for the rehabilitation of differently abled persons using EMG sensors as the input source for the movement of the exoskeleton. The design was too big to be worn but the design was the first to use an exoskeleton for medical purposes. [8]

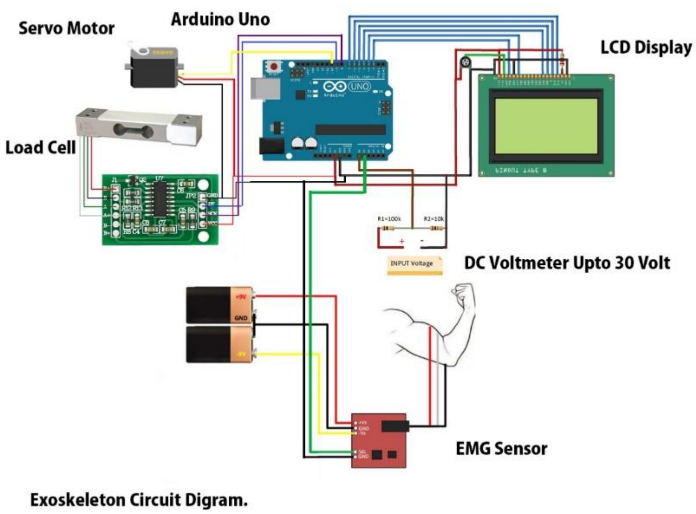
The design of the following project is influenced by the UCLA's exoskeleton but contains many distinct features such as the design will be a device the user will be able to wear and it adds features such as a weight sensor to display the amount of weight is being lifted and other features such as the angle of the movement of the arm and the number of electrical pulses the biological arm is creating. [18] Also since the exoskeleton will be mobile the power that the exoskeleton need will be coming from the battery and the battery voltage will also be displayed on the screen. [13]

VIII. Proposed Design

The research design uses an electromyography sensor and its electrodes to acquire the data that is needed for the movement of the arm. (Fig 3) The data is then sent to an analog to digital converter to convert the raw data into digital signals and then the data is passed on to the Arduino. [16] The

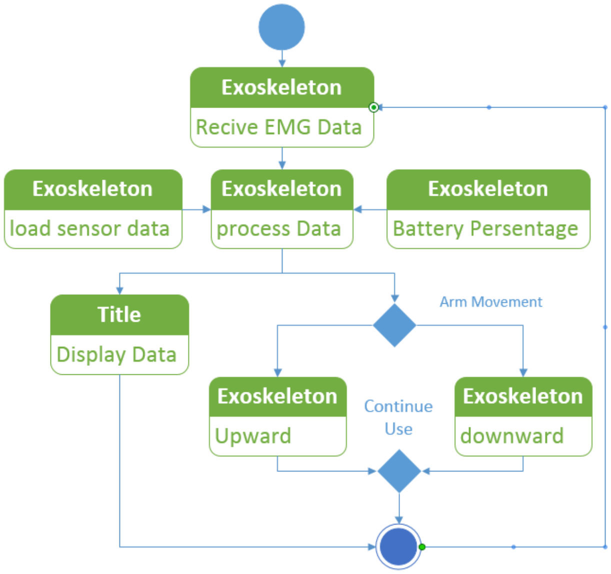
Arduino then uses the digital signals to determine at what angle the servo motor moves in order to mimic the movement of the biological arm. This is done by using multiple conditions that are coded into the Arduino. [17] The conditions that determined the input of the EMG sensor at runtime also instructs the servo motor to move accordingly. (Fig 3)

For the use of doctors and therapist, the movement of the arm is also shown as an angle the arm moved using calculated data from the Arduino (Fig 3), this can help therapist determine the range of movement the biological arm has and how much it has improved over time. The system also displays the weight that is being lifted by the arm using a load cell. (Fig 3) The battery percentage is also shown using a DC voltmeter to remind the user to recharge it when it runs low. (Fig 3)



(Figure 3: Exoskeleton Circuit diagram)

In (Fig 4) the first action that the device performs is it gathers electronic signals from the muscles of the biological arm and sends the raw data to the EMG sensor where the raw data is amplified extensively because the signals coming from a disabled arm are weak and it is not enough to convert it into digital signals, analog signals are then converted into digital signals. [16] After the signals have been converted, the signal goes through a microcontroller where these signals are rectified and calculated to generate a command which moves the device through DC servo motor. At runtime, the device also collects data from sensors that is information of load, battery percentage and position of the biological arm that is to be displayed on LCD display mounted on the device for observation. This cycle continues until the user turns it off. [13]



(Figure 4: Exoskeleton state diagram)

IX. Result

The result is a device that is can be used to help the disabled by mimicking the activities of the disabled hand. Since the device is connected to the biological arm the device reads the electrical data from the biological arm's muscles and performs the same task as the biological arm is performing. This action gives the biological arm extra strength to manipulate the arm as the user wants which is necessary because the disabled arm lacks the strength for complete movement. The device can also be used for power augmentation function in which the device will be used as a strength enhancer for regular users making them capable of lifting more weight than they can be using only their biological strength. One more application of the device is that it can be used as means of rehabilitation of the arm that has been temporarily damaged by an accident. It can help the patient recover faster and can also be used to work at the regular pace while the arm recovers from damage because the device will handle the load that is exerted on the arm during the recovery period. [18]

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