EMG based Exoskeleton for Left Hemiplegia patients

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Abstract. Paralysis is a condition in which the muscle function is lost in a partof the body. Paralysis is mainly caused as a result of severe stroke, where in the blood supply to a part of the brain is cut off. Hemiplegiais a type of paralysis which affects half of the body includes one arm and one leg on the sameside of the body. The case of left Hemiplegia is taken into account, which is caused by the absence of blood supply to the righthemisphere of the brain. Stationary systems like Lokomat, used in the rehabilitation centres to assist training, provide highly repetitive action and just assistance to the patient's capabilities while walking on a treadmill. However these systems are not portable and cannot beused for home or daily activities. To overcome this, this paper presents the rehabilitation system, which comprises of an exoskeleton that aids the movement of the left upper limb. The entire system is driven by a motor through a microcontroller system which assists patient's flexion and extension movements. Meanwhile, EMG signal can be recorded by placing surface electrodes to know the recovery of physiological motor function.
Keywords *- Hemiplegia, stroke, rehabilitation, upper limb, Electromyography (EMG), exoskeleton, flexion, extension*

1. Introduction

The biggest single reason for long term grown-up handicap in Europe is stroke. Roughly 110000 individuals have a stroke every year in UK with more than 900000 alive having endure a stroke. Generous extents of these patients are left with huge residual handicap, incorporating hemiparesis in right around one half of patients. Therefore, one of the best wellbeing impacts for patients, their families and the economy results from long term physical and psychological outcomes of stroke. By 2030, stroke pervasiveness is relied upon to increment by 25% in the USA, generally because of a maturing populace [1]. Lately numerous individuals are influenced with hemiplegia. The Indian Council of Medical Research assessed that, there were 9.3 lakh instances of stroke and 6.4 lakh expired because of stroke in India. The quantity of new cases every year remains at around 100,000; it costs the NHS £2.3 billion per year to treat and care for stroke casualties.Health care professionals such as physical therapists play a large role in assisting these patients in their recovery hence the training duration is usually limited by personnel shortage and/or exhaustion of therapist.Physiotherapy is a labor intensive, manual assisted training and therefore training duration is usually limited by personnel shortage and/or exhaustion of therapist [2-3]. Moreover in recent times, the problem has been increased with increase in number of people affected by hemiplegia.Existing systems like the Lokomat, the LOPES or the ALEX are stationary systems and used in hospitals or rehabilitation centers [4] to assist the rehabilitation training. They provide highly repetitive training and adjust the assistance to the patient's capabilities. However these systems are not portable and cannot be used at home or for activities of daily living. The proposed system consists of an exoskeleton or a rehabilitation system that provides necessary and required movements of the upper limb without depending upon physical therapists, and just by driving the system using a motor driven circuit**.** The main aim of this paper is to design and experimentation of an actuated exoskeleton for the functional recovery of a left hemiplegic patient using his/her EMG signal [1].

2. Materials and Methods

2.1. Etiology of Hemiplegia

The word 'plegia' signifies shortcoming or weakness. 'Hemi' suggests one part of the subject or body. Subsequently, 'hemiplegia' signifies overall sense and nerve function loss (paralysis) of one half of the human body, which including one arm and leg. Any sickness or injury in the physiological motor center of human can cause hemiplegia [2]. Half of the body influenced is not quite the same as the states of paraplegia and quadriplegia, which are regularly mistaken for Hemiplegia. Figure 1 shows the condition and reasons for left and right Hemiplegia [5].

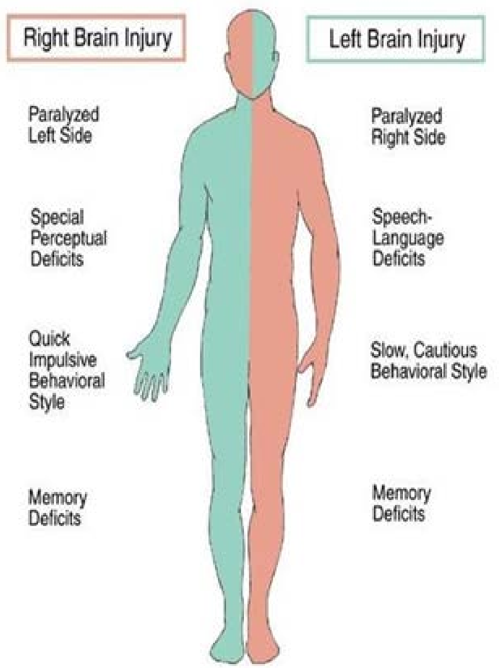

Figure 1. Left and right Hemiplegia

Paraplegia is loss of sense and nerve function in the two legs, underneath the waist. Quadriplegia is loss of sense and nerve function underneath the neck and is likewise typically the after-effect of a spinal cord accident [3]. It's brought about by harm to one portion of the brain; explicitly, when that damage influences the parts on which half of the human brain has been harmed. This can happen during childbirth, or may happen after birth because of stroke, cerebral paralysis, perinatal strokes in babies, and horrible cerebrum injury. In the event that the individual encounters injury on the right side of the head, at that point the left half of the body will be influenced [6]. On the off chance that the individual encounters injury on the left half of the head, at that point the right side of the body will be influenced.Right hemiplegia will occur when the left portion of the brain is damaged..Left hemiplegia often presents when the right portion of human brain is altered or damaged. It usually presents with Loss of control over purposeful movements, unable to use objects correctly and unable to draw, comb hair or cook [2,7].

2.2. Hardware Implementation

This pictorial representation in figure 2 illustrates the design and development of the upper limb exo-skeleton model, which is powered by 12V rechargeable battery. Unaffected upper (right) limb position is detected by using a sensor, and with the help of microcontroller the training can be provided for affected limb ofhemiplegic subjects. EMG signal can be recorded and analysed [8] by placing surface electrodes to know the recovery of motor function.

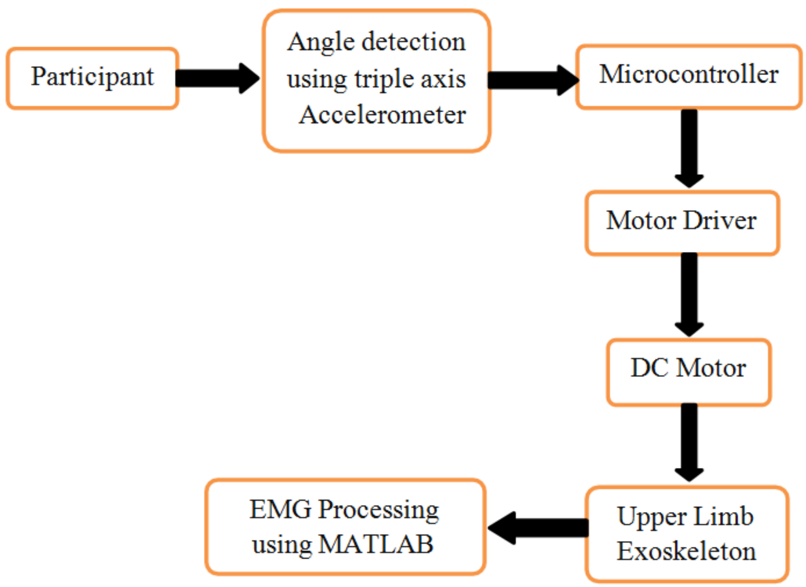

Figure 2. Pictorial Representation of Entire system

2.2.1. DC Motor

In order to operate the exoskeleton, DC motor is used, which will convert electrical power into mechanical power, through the interaction of two magnetic fields. The specification of motor used in the system is shown in table 1.

Table 1. Specification of motor used in the exoskeleton

Motortype	DC
Voltage	12V
Current	2 amp
Othercharacteristics	Permanentmagnet
Torque	14.7Nm
Power	560tts (0.75hp)

The driver used along with this motor is L298. This dual bidirectional motor driver is based on the very popular L298 Dual H-Bridge Motor Driver IC. This Dual H-Bridge driver will allow easy and independent control of two motors up to 2Aand voltages up to 46V each in both directions [7].

2.2.2. Microcontroller and accelerometer

The microcontroller plays major role in exoskeleton function and operation. The position computed and programmed in the controller will be executed through exoskeleton. Arduino Uno microcontroller board based on the ATmega328P is used. The angle of the subject corresponding to exoskeleton is measured by accelerometer. Here, MPU6050 – 6 Axis Accelerometer is used, which has 3-axis gyroscope and a 3-axis accelerometer on the same silicon die together with an onboard Digital Motion Processor.

2.2.3. EMG acquisition

Electromyogram (EMG) is the graphical representation of the biological electrical activity of the human muscle, which can be recorded using electromyograph. Here, we acquire the EMG signal through surface electrodes [2, 7]. It is recorded to know the recovery status of the muscle after the movements by exoskeleton. In this experimentation, EMG signals is acquired using both systems, each have similar signal-conditioning unit, they are BIOPAC MP36 and MYOWARE muscle sensor. BIOPAC is four channel sophisticated data acquisition system for all biological signals like, ECG, EEG, EMG, EGG [8,12], EOG signals. The drawback is that system is not wearable [14]. But MYOWARE sensor is wearable sensor which can be incorporated with subject easily. It holds all miniaturised signal conditioning units inbuilt. The signal acquisition is done in both systems for comparison [9-11, 15].

2.2.4. Exoskeleton Model

An exoskeleton is a wearable system that provides a basic support for the patients in assisting his/her movements. Thus its design must be patient-friendlyand does not injure the patients in any manner.

Figure 3. Photograph of exoskeleton model

The exoskeleton can be powered using motors, actuators or other driver circuits. The exoskeleton must be capable of lifting heavy weights without causing any discomfort to the patients [13]. The upper limb exoskeleton used in this work is shown in the Figure 3.

2.3. Software implementation

2.3.1. EMG Processing

The MATLAB software is used to process the EMG signal is which is acquired from the subjects [2]. The EMG data is acquired by using MYOWARE muscle sensor and BIOPAC system software with a sampling frequency of 1000 Hz.

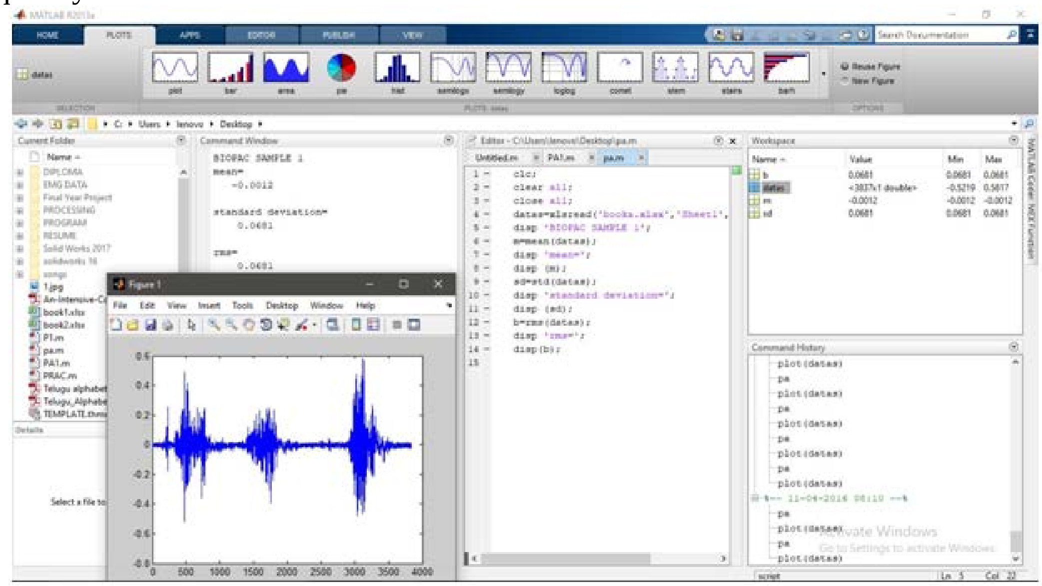

Figure 4.MATLAB processing of EMG acquired using BIOPAC for subject 1

The amplitude values are stored in an excel spreadsheet. These values are imported to MATLAB for further processing [8]. The mean and standard deviation is calculated from the obtained values (table 2). The calculated values from MYOWARE and BIOPAC system software are compared in MATLAB and analysed.

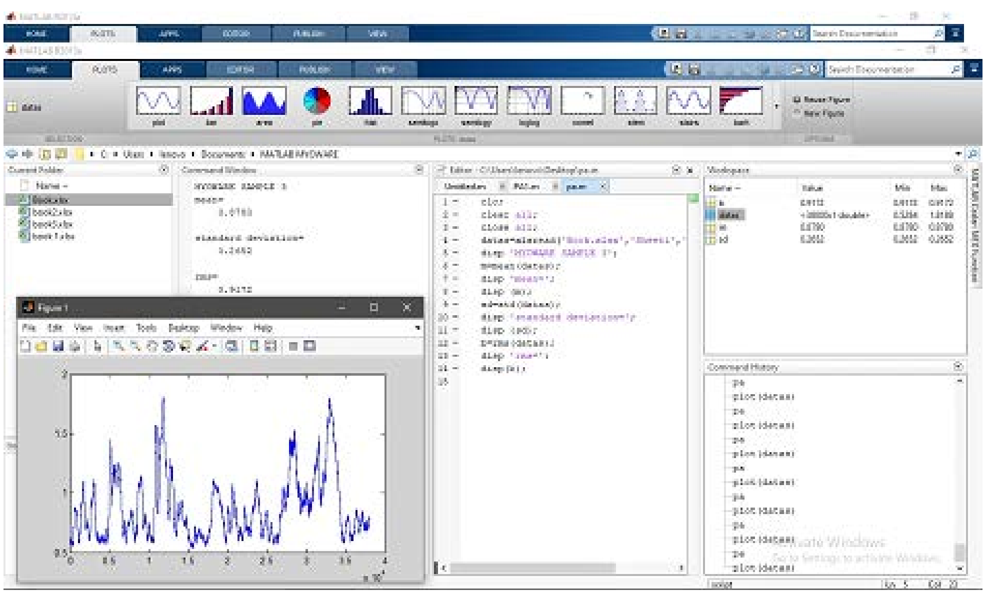

Figure 5.MATLAB processing of EMG acquired using MYOWARE for subject 1

The processed waveform obtained from both BIOPAC and MYOWARE of subject 1 is shown in Fig. 4 and Fig. 5.

3. Results and Discussion

The complete setup which includes the exoskeleton model with the motor attached, and the power supply is shown in the below Figure 6.

Table 2. Statistical Comparison of EMG acquired using BIOPAC and MYOWARE

SUBJECT	BIOPAC EMG			MYOWARE EMG		
	MEAN	SD	RMS	MEAN	SD	RMS
1	-0.0012	0.0681	0.0681	1.6465	0.9998	1.9263
2	-0.4648	0.1057	0.4766	0.878	0.2652	0.9172
3	-0.0021	0.0836	0.0836	1.809	1.2974	2.2268
4	-0.0013	0.0939	0.0939	1.7731	1.0137	2.0424

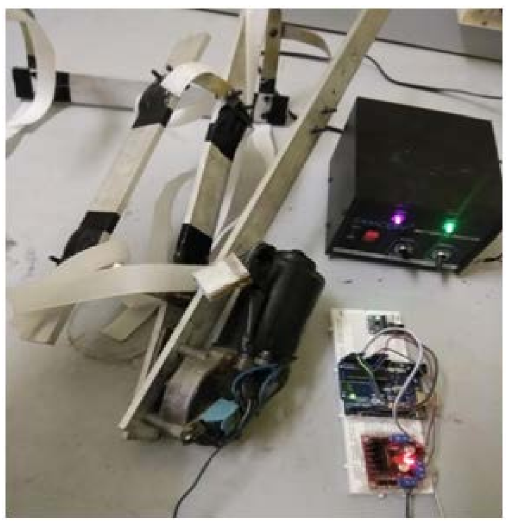

Figure 6. Photograph of the overall Setup

The exoskeleton is connected to the left upper limb of the subject and the circuit with the accelerometer is connected to the right upper limb. So when the subject lifts his/her right limb the exoskeleton moves in accordance with it. Figure 7(a) represents the position of the upper limb exoskeleton at an angle of 45˚. When the subject moves his/her right limb from an angle 45˚ to 90˚ is shown in the Figure 7 (b). The exoskeleton moves to a particular angle based on the movement of the healthy limb whose angle is detected using the accelerometer. The movement at angle 115˚ and 140˚ is represented in the Figure 7 (c) and (d).

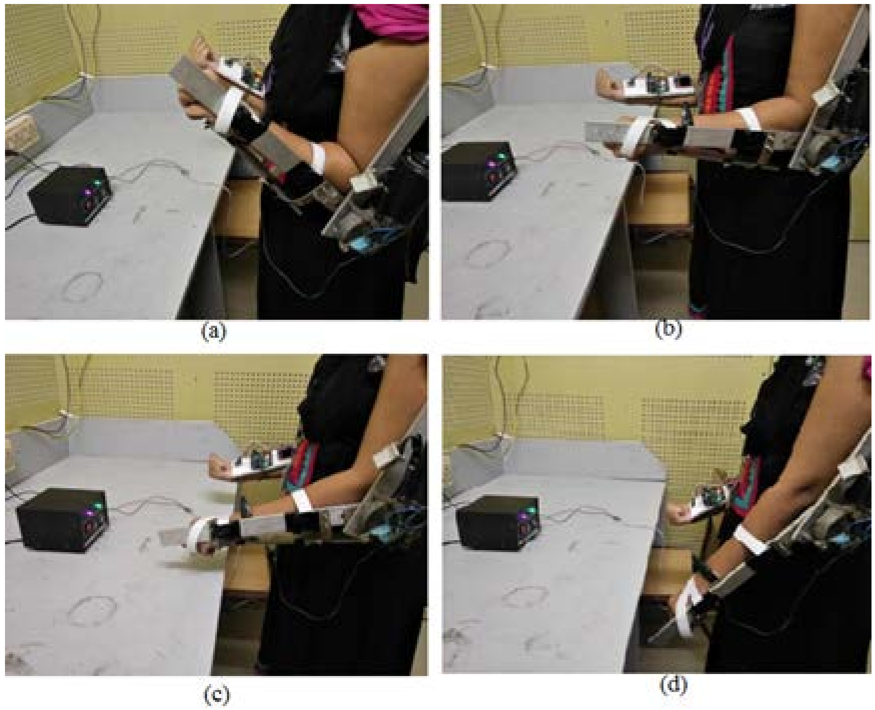

Figure 7. Photograph of upper limb exoskeleton at various angle

4. Conclusion

As of the present work shows the hardware of upper limb rehabilitation system for left hemiplegic patients. The exoskeleton is driven by DC motor fixed at elbow joint. Hemiplegia treatment approach includes the diagnosis, management and proper care of patients suffering from paralysis to support their activities of daily living. This exoskeleton plays a major role in functional recovery of the muscles by acquiring the angle movement from the patient's own right hand. In future, this project work can be carried out by using an EMG sensor for controlling angular movement of the upper limb. The work can also include providing individual control units for each action of the limbs, thus assisting the hemiplegic patients in sooner recovery with minimal strain during the therapy procedure, and without depending upon the physiatrist.

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