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EMG based FES for post-stroke rehabilitation

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Abstract. Annually, 15 million in world population experiences stroke. Nearly 9 million stroke survivors every year experience mild to severe disability. The loss of upper extremity function in stroke survivors still remains a major rehabilitation challenge. The proposed EMG Abstract—Annually, 15 million in world population experiences stroke. Nearly 9 million stroke survivors every year experience mild to severe disability. The loss of upper extremity function in stroke survivors still remains a major rehabilitation challenge. The proposed EMG based FES system can be used for effective upper limb motor re-education in post stroke upper limb rehabilitation. The governing feature of the designed system is its synchronous activation, in which the FES stimulation is dependent on the amplitude of the EMG signal acquired from the unaffected upper limb muscle of the hemiplegic patient. This proportionate operation eliminates the undesirable damage to the patient's skin by generating stimulus in proportion to voluntary EMG signals. This feature overcomes the disadvantages of currently available manual motor re-education systems. This model can be used in home-based post stroke rehabilitation, to effectively improve the upper limb functions.

1. Introduction

Stroke is currently the prime cause of neurological disability [1]. There are 1.6 million reported cases of strokes in India and 330-420 out of 100,000 adults in cities and 83-262 per 100,000 people in rural India are affected by stroke [2]. The chances for occurrence of disability among stroke survivors are 24-54%. The studies show the significant decrease in mortality due to stroke in the last few decades. But there is a subsequent increase in the rate of impairments and disabilities in stroke survivors [3]. The stroke weakens the muscles in the body and impairs the joint movement, making coordination difficult. This in turn affects the daily physical activities such as walking, grasping objects, eating and swallowing. It can also induce painful muscle spasms.

The most common are physical impairments in stroke survivors are difficulty in the functional use of upper limb and walking. Upper extremity hemiplegia remains the primary impairment in many stroke survivors. The greatest proportion of post stroke recovery occurs in the first 3 to 6 months. There

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can be a further improvement in function up to 18 months in some patients. Though, after 3 months 20% of the stroke survivors are able to regain normal upper extremity function and 20% regain no functional strength [5]. These limitations are caused not only because of neurological impairment; it also results from the physical deconditioning due to inactivity. Ignoring the effect of physical deconditioning in post-stroke impairment, in patient leads to compromise in quality of life and increase the risk of further stroke.

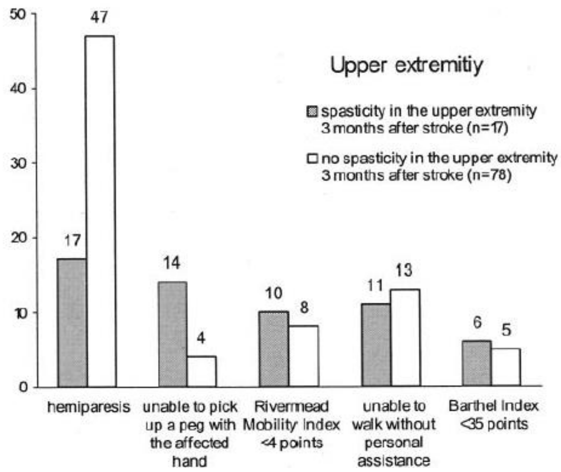

Figure 1. Hemiparesis and severe disabilities-3 months after stroke among patients with and without spasticity in the upper extremity [7].

Thus the post stroke rehabilitation techniques have a growing interest in neurophysiological therapy, since it can improve the functional outcome and quality of life of many stroke survivors. Functional electrical stimulation (FES) is a neuroprosthetic technique applies programmed short electrical pulses to the muscles affected by stroke for restoring lost motor function. It can be either the hemi paretic muscles or to the peripheral nerve system associated to the hemiplegia. Functional electrical stimulation can be used for correction of contractures, muscle strengthening, facilitation of voluntary motor control and increased passive range of motion. The FES can also used for improvement muscle spindle reflex activity [4]. Recent clinical studies promote the use of FES for the recovery of muscle strength after stroke. FES specific for the upper limb rehabilitation has been receiving increasing attention as a therapeutic modality due to clinically significant results [5].

2. Methodology

This section gives a brief idea about methodology followed in this project, which includesblock diagram, hardware design, and the algorithm of the model.

2.1 Block Diagram

The below block diagram explain the working of the proposed model.

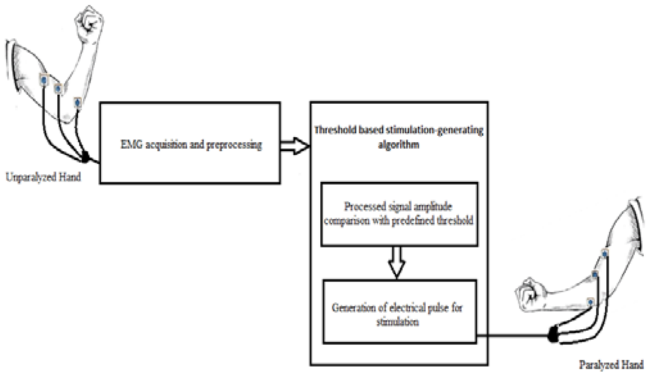

Figure 2. Block Diagram.

Hemiparesis is paralysis of half of the body. It's one of the most common after effect of stroke [6]. To restore motor function in hemiplegic patients advanced rehabilitation techniques are followed. In this project a Functional electrical stimulation applied to the paralyzed hand based on EMG signal from the un- paralyzed hand as an effective therapy for upper limb hemiplegia.

Figure 3. Generated electrical pulse for stimulation given to paralyzed hand [5].

The model in figure [3] suggests a prototype for assessing this novel FES strategy based on surface EMG. Voluntary contraction of the unaffected hand muscles produces a proportional mode intensity of stimulation to the paralyzed hand. This model enables hemiplegic patients to practice real world tasks.

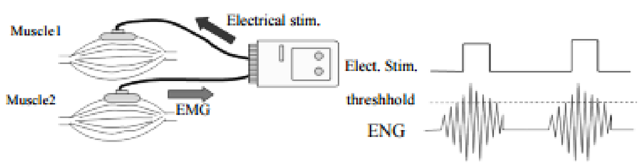

Figure 4. Schema of EMG-triggered FES.

The signal acquired by surface electrodes placed at specific locations in muscle. The frequency range of the signal lies in-between 50 - 150 HZ and it's followed by Signal pre-processing. Here the surface electromyography (SEMG) acquired as an indicator of muscle force [1]. The proposed

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methodology follows a threshold based stimulation-generating algorithm. Multilevel thresholds for the different magnitude of the SEMG signals are determined and maximum frequencies are set within the threshold based stimulation-generating algorithm.

When the amplitude of the SEMG exceeds the predefined threshold level, one electrical pulse for stimulation with required specifications is triggered. In a similar way for each predefined threshold level electrical pulse of required amplitude is generated. The maximum intensity of generated pulse sequence determined with respect to the maximum frequency. To boost the performance of the algorithm, the threshold levels and maximum frequency need to be chosen with proper evaluation and care.

2.2 Algorithm

Algorithm for the working of the proposed system is given below:

The model will work based in multiple threshold mode. In this model of FES, three different trigger pulses are generated based on the amplitude level of EMG acquired from patient's unaffected arm. When the threshold of EMG goes beyond the predefined minimum value, the mode 1 will be triggered with defined amplitude and pulse width. Based on the increment in the EMG amplitude, the modes of trigger will automatically vary from one to three. A delay is introduced between each trigger to minimize the effect of burning and other adverse effect, even if the patient is overstressing themselves for generating EMG for a long period of time.

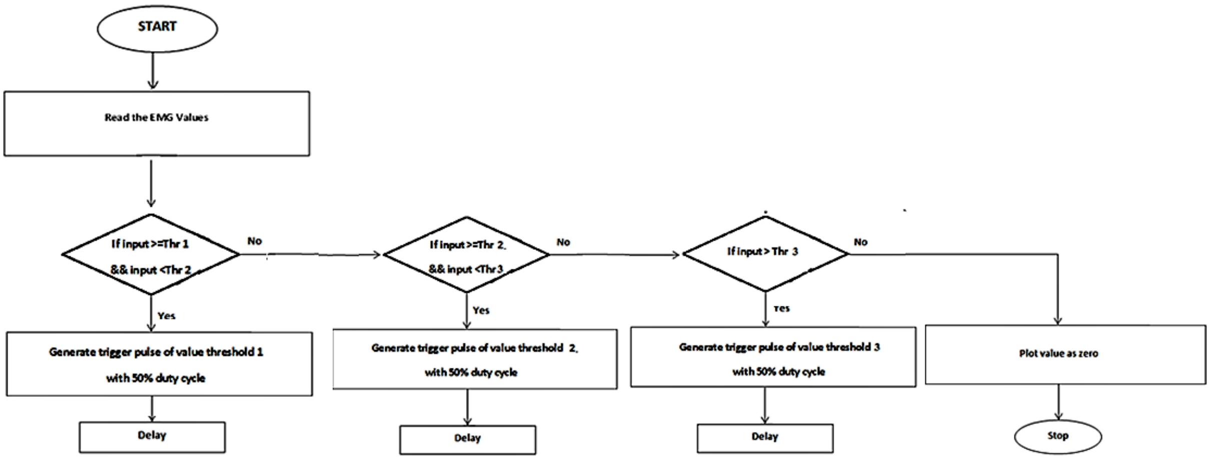

Figure 5. Threshold Based Stimulation-Generating Algorithm.

3. Results and discussions

Stroke is a main cause of neurological disability in adults as it leads to functional disability of limbs. Electrical stimulation, especially functional electrical stimulation can use as a therapeutic tool to facilitating recovery of function by in improving motor performance in the hemiplegic upper limb. FES can use for the improvement of the motor reaction time, co-contraction of muscles and isometric torque.

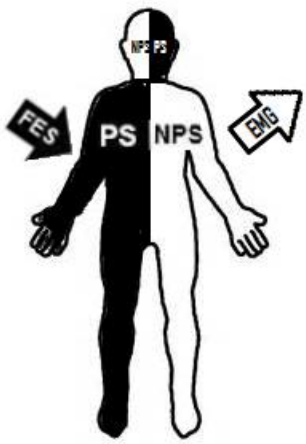

Figure 6. Schematic representation of stroke patient

3.1 Testing of FES

The designed system is tested with the help of variable resistor. When the values of variable resistor changes within the defined intervals, the trigger pulses are generated with varying amplitude.

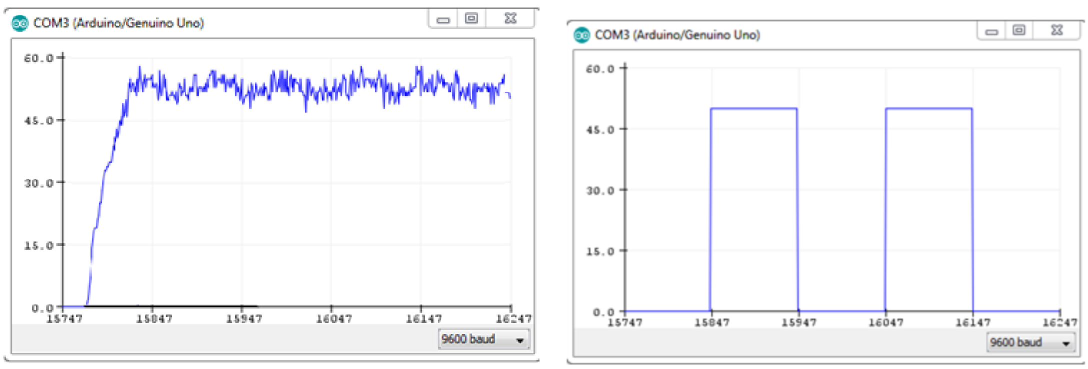

Figure 7. Testing using variable resistor.

3.2 Stimulation pulse train

The typical stimulation pulse waveform used for transcutaneous FES is a biphasic square-wave waveform with pulse duration of 5ms, frequency of 200 Hz and current value of 40mA. The amplitude will vary from 1V to 3V based on mode. The biphasic waveform is used to avoid the tissue damage due to galvanic processes.

Figure 8. Stimulation pulse for FES

This model works based on the proportionate mode, have three different sets of voltage level for each mode of operation. For the first mode, when the EMG level exceeds the minimum threshold, the mode-1 will be triggered with amplitude 1V. For the second threshold level of EMG (mode-2), the designed amplitude is 2V and. When the EMG signal exceeds the maximum predefined threshold, mode-3 will be triggered with voltage value 3V. The trigger pulses are generated with a frequency 200HZ.

3.3 Trigger generation in FES

The trigger is generated when the EMG threshold exceeds the predefined value. Figure 9 shows the single threshold condition in which the trigger pulses of single amplitude and 5ms pulse width is getting generated corresponding to EMG. Each pulse will last for 50ms.

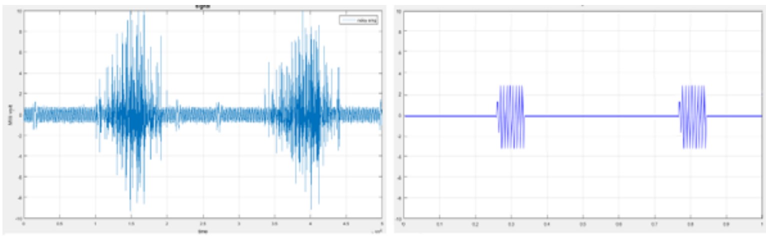

Figure 9. Trigger- Single Threshold

Figure 10 shows the multi threshold condition, in which trigger pulses of multiple amplitude will be generated corresponding to varying amplitude of EMG.

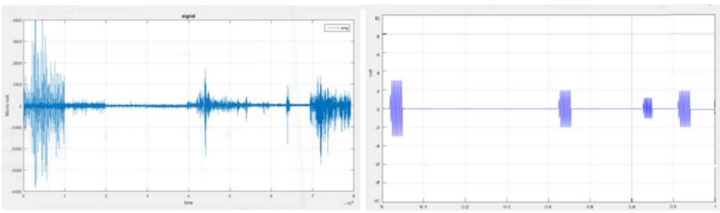

Figure 10. Trigger- Multi threshold

4. Conclusion

EMG-triggered FES is more efficient than non-triggered FES in improving the upper limb functions in stroke patients in terms of voluntary muscle contraction and muscle strength of the affected hand. The whole idea has been delivered in a cost effective manner to give access to a large population of patients with post stroke

In this model, EMG signal acquired from the paralyzed limb used to generate proportionate electrical stimulation to the affected muscle target. EMG signal picked up using surface electrodes from the target .Simultaneously it used to stimulate the unparalyzed limb of same person proportionate to the acquired EMG signal using another set of surface electrodes. The mentioned mode operation insignificantly reduces the harmful effects, such as burning which occurred in currently available manual TENS modules.

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