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# AUTOMATIC RESISTANCE OF A REHABILITATION BICYCLE USING EMG SIGNALS

Sarthak Pandey, Joseph Shilumbu, Abhishek Patil and Deepa Madathil
School of Electronics Engineering, Vellore Institute of Technology, Vellore, India
E-Mail: deepa.m@vit.ac.in

**ABSTRACT**

Rehabilitation is the act of restoring one's health back to normal using medicine and engineered devices with the aim of recovery. Rehabilitation engineering can be described as the design, development, and application of engineering methods and devices to reduce the problems faced by persons who have disabilities. The main objective is to use our engineering principles to develop a rehabilitation bicycle in which the resistance will be altered automatically based on the feedback from your own muscles. The feedback signals used to serve our purpose is electrical impulses from our muscles or EMG signals. The EMG signals are extracted and processed as fatigue is to be detected from these signals which will then be used for setting the resistance of the bicycle according to the level of fatigue detected. In this study there aremainly two objectives, one is the acquisition of the signal and processing it for detecting fatigue, and the second objective is integrating the fatigue detection values to the brakes to vary it automatically. Using the signals, to detect muscle fatigue, the parameters normally used are the amplitude and the frequency of the signal. Since the fatigue level varies according to individuals the detection is done real time at the start of the procedure. The studies in the literature show that the amplitude of EMG signals increases progressively as a function of time when the fatigue increases. Accordingly the muscle fatigue can be monitored by changes in the EMG frequency properties such as mean and median frequency. For the purpose the research however we are going to use the amplitude component of the signal to detect fatigue. After fatigue is detected on the signals, a threshold is set at a suitable voltage where amplitude spikes of fatigue have already begun. Therefore after sometime if the amplitude continues to rise above that threshold it triggers a motor or plates to vary the resistance. The results of this research, we believe will lead to faster, accurate and progressive healing of patients and athletes.

**Keywords:** EMG, rehabilitation, fatigue, resistance, LabView.

## INTRODUCTION

Rehabilitation is a field in medicine which still remains technologically backward with respect to other fields in medicine. The inadequacies in rehabilitation is currently leading to slower recovery rates among patients, inaccurate treatment and many other more issues. The aim of our research is to develop a fully automated rehabilitation bicycle where the resistance of the machine will be controlled by the feedback signal. To acquire EMG signals from the subject Invasive and non-invasive methods can be used. In the invasive method a needle electrode is inserted directly into the muscle through the skin. The non-invasive way is recorded with electrodes on the skin surface. Needle EMG recording provides a more exact representation and finer resolution of the electrical activity of the muscle fibers than that possible with surface EMG. However, surface EMG signals can still be used to extract a useable representation of muscle status [1]. For our research we have used the surface electrode.

After acquiring the signals the next step was to detect fatigue characteristics in the obtained signal. Fatigue is defined as the inability of the muscles to exert force or to maintain a certain level of force exertion. The issue of fatigue is complex due to the various physiological and psychological phenomena which contribute to it, and which demonstrate it. The ways of measuring fatigue are subjective because they rely on the cooperation of the individual. We have utilized the amplitude characteristics of the signal to determine fatigue level in a subject as the amplitude is said to increase with time as fatigue of a muscle increases [2].

Using software like Lab VIEW and Arduino, a threshold is set on the fatigue signal, which later is used to control the resistance of the device as per the needs of the patient or the athlete [3].

There are many factors that are contributing to the muscle fatigue depend on the mode and the intensity of the activity that one is doing. The low intensity muscle fatigue is different from the high intensity muscle fatigue (P. Bryant Chase *et al* 2011). This paper showed us a big differences of muscle fatigue depending on the activity being performed [4]. There are two types of fatigue: central fatigue and peripheral fatigue as explained by (Mohamed R. Al-Mulla *et al* 2011), the peripheral fatigue is a neuromuscular junction and muscle fatigue, while the central fatigue is the brain fatigue[1], however there are fatigue and Non fatigue as localized muscle fatigue. Once the fresh muscle starts to fatigue, new recruitment of muscle fibers occurs, the muscle fatigues is due to the accumulation of lactic acid in the muscle tissue and the depletion of glycogen (stored glucose).

Muscle fatigue creates a problem, in a way that it alters the relationship between the EMG signal generated by the muscle and the amount of force being generated. Fatigue is a potential risk factor for musculoskeletal disorders (Omid Haddad *et al* 2011), and being able to quantify muscle fatigue would be helpful to understand the underlying risk factors[5]. Muscle fatigues are measured as Electromyography (EMG) and EMG is defined as the evaluation of muscle depending on the muscle electrical activity (Didier Gamet *et al* 2001), this electrical activities (EMG signal) are then recorded form the muscles using

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various techniques muscles such as invasive and non-invasive techniques (R. Al-Mulla *et al* 2011), the invasive method involve the use of needles or incision to get the signals while the non-invasive method involve the placement of the electrode on the body surface. If the surface electrode is being used, the proper placement of electrode is very important to get accurate EMG reading. The placement of the electrode is very important, they can be placed on various anatomical location of the body which will helped to get good reading of the EMG[1].

There are many physiological factor that influence the quality of the EMG signals this include the number of activities, the quantity of tissue between the electrode, the surface of the muscle, location of the active fibers and the fiber type (Francisco Sepulveda *et al* 2011), other factors include the properties of the electrode and amplifier and the gel material used on the electrodes.

It is important to know the relation between the EMG signal and fatigue, how the EMG signal changes with fatigue. The amplitude of EMG signals increases progressively when the fatigue increases, as a function of time (Jos´e Bioucas Dias *et al,* 2008), in addition there is a linear relationship between the EMG signals as fatigue increases.

## METHODOLOGY

At the beginning of the project we started using MATLAB software but it was not giving us accurate reading then we have decided to use LAB View which was more easier and it has real time signal processing, even though LAB View is complex it does not include a lot of coding as in MATLAB.

Here we have discussed more how to acquire the signal, we have placed three electrodes, two of them on the quadriceps and one is a reference electrode. Electrodes were placed at the motor point and at the midline of the quadriceps muscles. Electrodes are placed at quadriceps since more power is used between the 12 o'clock and 5 o'clock position, as shown in Figure-1. This is when a majority of the primary muscles are activated. Hip flexion, along with hip and knee extension are the primary movements of a pedal stroke. Between the 6 and 12 o'clock position in the pedal revolution, there is some knee flexion to help bring the pedal back to the top but helping that flexion is the greater downward force being placed on the opposite pedal, by the opposite leg. According to the figure below it is much clear that quadriceps apply much more force to the pedal and is thereby used to obtain the signal. The burgundy colour is showing the force applied by the knee extensors and the red is showing the force exerted by the hip extensors. The figure shows that the force exerted by the hip extensors is more than that of the knee extensors however we still select the knee extensors because of the fact that signal acquisition from the knee extensors (quadriceps) is easier and convenient.

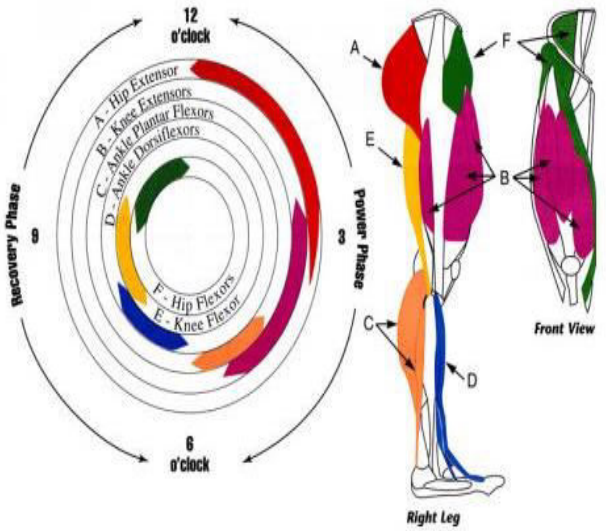


**Figure-1.** [6]

To acquire the signal surface electrodes with a Muscle sensor V3 was used[7]. The sensor gives a smoothened and rectified signal output. The signal is then processed in Lab VIEW where it's filtered again and thresholds are applied when amplitude peak starts to occur at an abnormal rate showing signs of fatigue.

We used a Butterworth Band pass filter to **limit** the bandwidth of the output signal to the band allocated for the transmission. The upper limit for the filter was set at 150Hz and the lower limit was 15Hz with a sampling frequency of 1100Hz.

To observe the measurement of EMG, a perception that the measurement electrodes are simply electrical terminals or contact points from which voltages can be obtained at the surface of the body and the electrolyte paste or jelly often used in such measurement reduces skin impedance of the system [8].

The circuit diagram used in Lab VIEW is shown below:

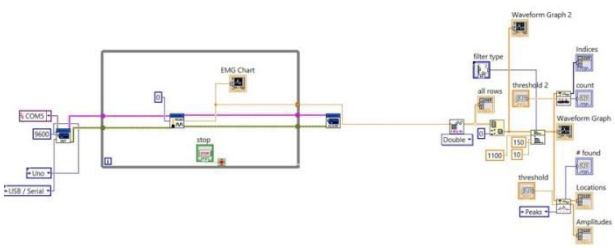

**Figure-2.** Lab View circuit.

After the threshold is applied the circuit is connected to a motor which in turn controls the resistance. If the signal keeps peaking above the threshold value then the resistance varies accordingly. In the circuit above the signal is obtained from the sensor which is used with the Arduino. The Arduino is then integrated to the software Lab View. Arduino is used for the signal acquisition and the resistance control, the muscle sensor is only

compatible with a microcontroller therefore Arduino was used for this research. LabVIEW is software which is used for filtering and processing of our signal. Therefore the obtained signal is processed with a band pass filter to remove any remaining noises. The signal extracted is analog in nature therefore we are reading the analog values and plotting them in a graph[9].

## MATERIAL USED AND SOFTWARES

- **Muscle Sensor v3 Kit**- Measure electrical activity of a muscle in Voltage (V)
- **Arduino:** To obtain data from the sensor and interfacing with LabVIEW.
- **LabVIEW (2016):** For real time signal processing.
- **Stepper motor:** This controls the brake which in turn determines the resistance according to the threshold set.

## RESULTS

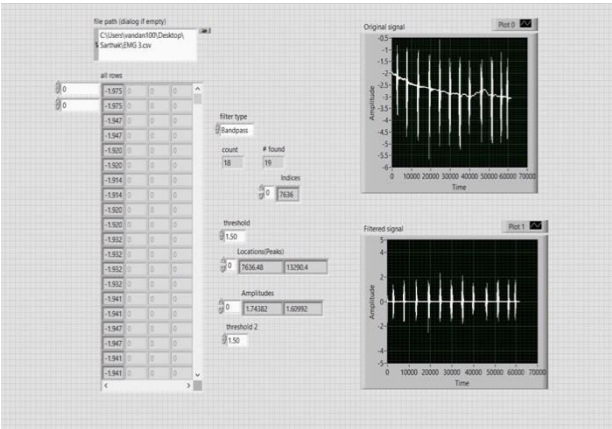


**Figure 3.** Processed EMG signal.

The above figure shows the output window of the LabVIEW program for the research. These results are obtained from the EMG signal of one subject, at a relaxed position and during maintained isometric knee extension at 60% of maximal voluntary contraction.

These are the conditions and output obtained after the signal processing:

- Threshold 1 was set at 1.50mV
- Threshold 2(peak) was set at 1.50mV
- Amplitude recorded 1.6-1.7 mV
- Results of 18 counts and 19 found amplitude that was over the given threshold.
  Using these results we have set 2 conditions:

a) If the amplitude is over the given threshold, then the resistance of the motor attached on the bicycle model is decreased automatically, for rehabilitation purpose.
b) If the amplitude is over the given threshold, then the resistance of the motor attached on bicycle model is increased automatically, to increase endurance for athletes.

Based on the output obtained from our research we were able to detect fatigue from subjects and use it to control the resistance of the Rehabilitation bicycle.

## CONCLUSIONS

More than half the patients that go through rehabilitation at hospitals complained about the procedure and felt like the change in the way of treatment could help the process better. The fact that treatment in this era of technology still conventional is the main reason we took up this research.

The purpose of this research paper is to develop a system automatically controls the resistance of the bicycle using muscle fatigue from the EMG signal obtained. The EMG signal was processed and analyzed in the Lab View software. The result has enabled us to develop a system which is capable of varying the resistance based on the feedback from the subject's muscles. This newly developed system can help patients recover faster, progressively and pain free. In athletes this system can be used to increase stamina, endurance and muscle growth which will lead to increase in performance of the athletes.

The system developed is a futuristic approach in the advancement of healthcare. As of now it is still in the development stage, however in the upcoming years we are expecting to develop the system as completely wireless with magnetic resistances. At the present we are using electrodes which are being connected to the microcontroller. The microcontroller is then connected to the software. This is making the system full of wires and complex. As for the resistance we are currently using Contact resistance brake, the defect of this brake pads are that it wears out quickly thereby increasing the maintenance costs. We hope to change this system as quickly as possible providing advanced rehabilitation bicycle for quicker and progressive recovery of patients.

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