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Real Time Muscle Fatigue Monitoring using IoT Cloud Computing

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***Abstract**: In this proposal a real time monitoring of muscle fatigue detection system is developed by using WemosD1mini board along with IoT environment. Surface Electromyography technique is used to acquire EMG signal of isotonic contraction by using EMG sensor inbuilt with D1mini Board, this signal preprocessed and sent to IoT cloud. In IoT cloud, signal is processed in time – frequency distribution method of bilinear time frequency distribution. From this method Median frequency and mean frequency are calculated. The downward shift of median frequency and decrement of mean frequency are taken as parameter for detection of muscle fatigue. The results are shown in GUI interface of any android mobile phone of user and health professional.*

Key Words- Surface Electromyography, Isotonic Contraction, Muscle Fatigue, Internet of Things, Cloud computing and WemosD1mini board.

1. INTRODUCTION

In the daily activities like Locomotion, Posture maintenance and powerful movements of human are depend on muscle system which generates required force and supervise them. Muscles are formed collection of motor units which consists of single alpha motor neuron and its innervated muscle fiber. The central nerve system gives stimuli to alpha motor neuron to generate the force. Electromyography is the signal generated by muscle due to activation of motor neuron present in the muscle cells. [1]

The decline of muscles to generate required force or inability of muscle to generate required force is called muscle fatigue. Due to lack of oxygen present in the muscle cells, the lactic acid is accumulated in the muscle during prolonged or repetitive work which forms the muscle fatigue.[1] Fatigue detection is applied in various fields like Rehabitation, Functional electric Stimulation, Ergonomics and sports medicine. The Acquisition of EMG is divided in two methods like Invasive and Non – Invasive. Among these two methods Non-invasive is painless method and mostly employed most of the bio signal acquisition system. The various methods of non-invasive EMG acquisition are Surface Electromyography, Mechmyography, Sonomyography, Acoustic Myography and Near –Infrared Spectroscopy.[4] The Surface EMG the most common method to collect the EMG because painless and easy to employ.[1]

When the muscle length is not changed during the work then muscle contraction is called isometric contraction, if muscle length and join angle moves then the contraction is called isotonic or dynamic contraction. The EMG signal in the isometric contraction is stationary and in the isotonic contraction is non Stationary. [2] Many researchers concentrate Isometric contraction but daily life activities like lifting weights, walking and running are isotonic contraction, Signal in the isotonic contraction more complex due to non stationary. Time domain approach EMG feature like RMS Value, mean approach value, average rectified value, Zero crossing, waveform length and slope sign changes not applicable for non-stationary signal. The frequency domain approach like FFT and STFT does not satisfy EMG features of non-stationary signal.So the time –frequency distribution method is best to get parameters of EMG which is used to find fatigue condition.[1]

Internet of things (IOT) is a connection of many objects through internet. It will connect man to man, man to object, object to object and Object to man via wireless or wired communication to achieve goal with efficient way. Wearable Internet of Things (WIoT) is an emerging technology ideal for influencing healthcare domain by creating an ecosystem for automated telehealth interventions. So this technology comfortable for monitoring fatigue condition which is used to real time monitoring of fatigue for sport persons .[10]

In this paper, we present the design and implementation of IoT cloud based wearable muscle fatigue detection system. In section 2, we present proposed model of EMG acquisition system. Section 3 presents Results and our conclusion is in section 4.

2. PROPOSED MODEL

2.1 Description

In order to overcome the challenges of traditional invasive methods, here we introduce IoT based a non-invasive measurement prototype for measuring Muscle fatigue. By this proposed model we can able to collect and analyze the current time data of user, through this it is possible to prescribe the suitable life style challenges well in advance, so the proposed prototype ensures that the safe living of user (Sports person) and incase of any abnormal condition, it alert the user as well as the pre-determined health care profession by means of various way

Here introduce a simple, small size, minimum power IoT enabled prototype for muscle fatigue, its flow diagram is shown below.

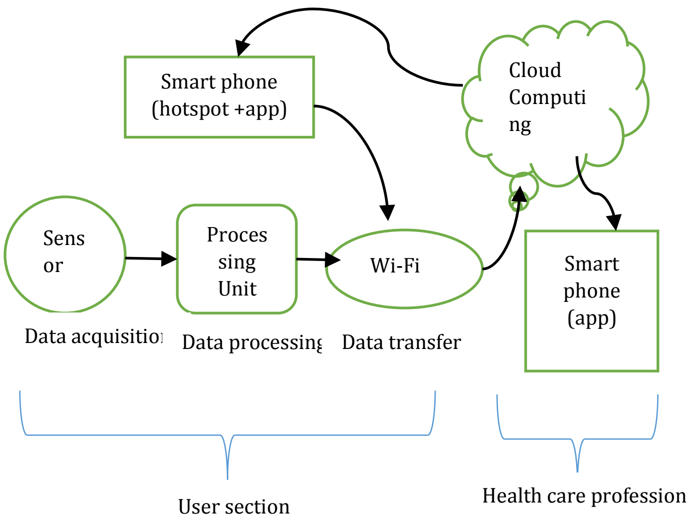

Fig.1 General Block diagram of proposed system

It is seen that, in the user section there is a sensor used for real time data acquisition and the collected data upload to an IoT cloud by using D1miniboard along with a Wi-Fi unit after processing it by a processing unit. From the cloud, the user as well as the health care profession can visualize the real time health details of user through their smartphone, each and every individual user and healthcare professions are need to be have a unique cloud id, then only they can be able to access the data.

2.2 WemosD1miniBoard:

It has been designed for mobile, wearable electronics and Internet of Things Applications with the aim of achieving the lowest power consumption with a combination of several proprietary techniques. It consumes about 60uA in working mode.

Fig.2 WemosD1Mini Board

Highlights

- Comfortable: Due to the small size and compatibility, the user can wear like a wrist watch and sensor like ring on finger.
- User location tracking by using the location tracking facility of smartphone app.
- 2D visualization bio signal by Smartphone app.
- Single Biosensor.
- Due its low cost suitable for all kinds of peoples in society.

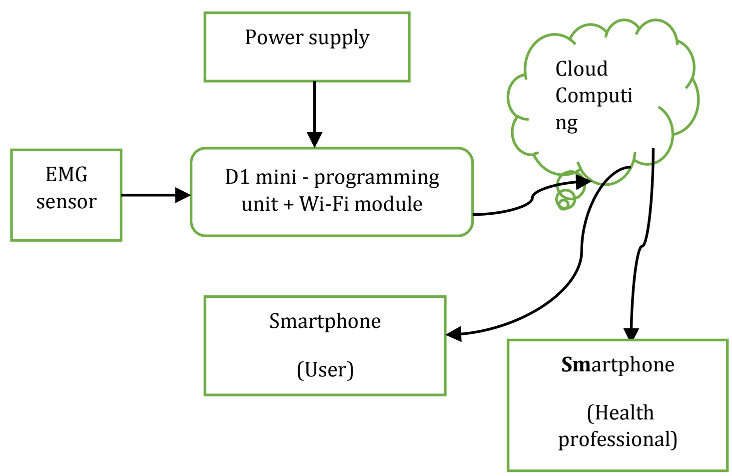

Fig.3 Block diagram with Technical specifications

The WemosD1 mini board is a small size advanced microcontroller based programming unit and it have an inbuilt 802.11b Wi-Fi module. The Wearable EMG Sensor is the only sensor used here, the sensor data are processed by D1 microcontroller and upload to the cloud, it is a open source IoT cloud by D1 inbuilt Wi-Fi module by using the internet connection of smartphone through its hotspot network. In that cloud each and every user have a unique id and by using that, the real time data are monitor and access by corresponding health care profession on a smartphone app, the user can also do the same by using his/her own smartphone app.

2.3 Signal Processing in Cloud Computing:

A four layer Cloud platform is used for EMG signal processing

Layer 1: Acquisition of the EMG Signal

Layer 2: Preprocessing of EMG Signal i.e. filtering of high frequency noise, motion artifacts and power line frequency

Layer 3: The Original EMG Signal are characterized by using pre-definedalgorithm i.e., the instantaneous median frequency and mean frequency are calculated

Layer 4: Statistical analysis of the post-processed results obtained in the previous layer to provide meaningful information to the end-user i.e., Visualization of EMG using mobile phone.

MATLAB based cloud computing is used to detect the parameter of EMG signal. The raw EMG is sent to cloud for processing from D1miniprocesor.A band pass filter (10-400Hz) is used to remove high frequency noise and Notch filter (50Hz) is used remove powerline and motion artifacts.Time – Frequency distribution is best tool to analyses the EMG features. Here we introduced bilinear time –frequency distribution for EMG signal analysis.

The General form of Cohen –Class Distribution is defined as

$$\rho_z(t,f)=\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} g(v,\tau)A_Z(v,\tau)e^{j2\pi(vt-f\tau)}dvd\tau \qquad (1)$$

where $\rho_z(t,f)$ is the time frequency distribution matrix , $g(v,\tau)$ is a weighting function or Doppler –lag kernel , v is Doppler frequency and $A_Z(v,\tau)$ is an ambiguity function.

The Bilinear Time –Frequency distribution is defined as,

$$g(v,\tau)=\int_{-\infty}^{\infty} G(t,\ \tau)e^{-j2\pi vt}\,dt \qquad (2) \text{ and}$$

$$G(t,\tau)=\left[\frac{\tau}{coshh^2\ t}\right] \qquad (3)$$

The following features are extracted from the above distribution

Instantaneous Median Frequency:

The frequency at which the power spectrum is divided by two equal half is called median frequency. The instantaneous median frequency (IMDF) at each instant of time sample n can be expressed by (4)

$$IMDF(n)=\sum_{k=M1}^{L} P[n,k]=\frac{1}{2}\sum_{k=1}^{L} P[n,k] \qquad (4)$$

$IMDF(n) = f_{M1}$

Where M1 is the frequency bin associated with the median frequency f_{m1} at the instant n, P[n,k] is the power spectrum of n^{th} time sample at the frequency bin k, L is the total length of frequency bin.

Mean Frequency:

Mean power frequency is defined as the sum of product of frequencies and its corresponding power divided by the total sum of power. The instantaneous mean frequency is obtained from the time frequency spectrum by replacing the power density spectrum. The mean frequency is defined as (5)

$$INMF(n)=\frac{\sum_{K=1}^{L} fP[n,k]}{\sum_{K=1}^{L} P[n,k]} \qquad (5)$$

Where f is the frequency value of power spectrum at the frequency bin and f_L Maximum frequency corresponding to L_{th} bin.

3. RESULTS AND DISCUSSION

Experimental Method

In this Research we concentrated isotonic contraction for analyzing muscle fatigue. The Subject was requested to do curl exercise 6kg dumbbell using their dominant hand until they got tired .The subject was advised to perform the excise in comfortable speed with following SINAIM norms for EMG Acquisition. The collecting system is like a band and it was wearied in their dominant arm. The Electrode in the wearable system employed dry polymer which reduces motion artifacts.

Fig.4 Dumbbell Exercise with EMG Acquisition

A raw EMG signal in isotonic contraction is collected by using WedemosD1 Mini Board as shown in fig5. By applying Time –frequency distribution in the EMG signal the mean and median frequencies were calculated. The decrement of mean and median frequencies shows (fig .6), the muscle got fatigue. The GUI interface of mobile phone showed the result. This was viewed by the user and health professional. In this method the user monitored the fatigue condition in real time. So the easily check their health condition

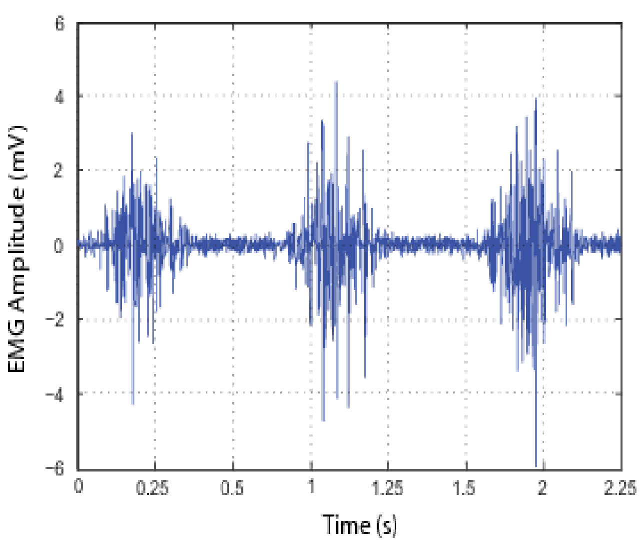

Fig. 5 Raw EMG signal in dynamic contraction

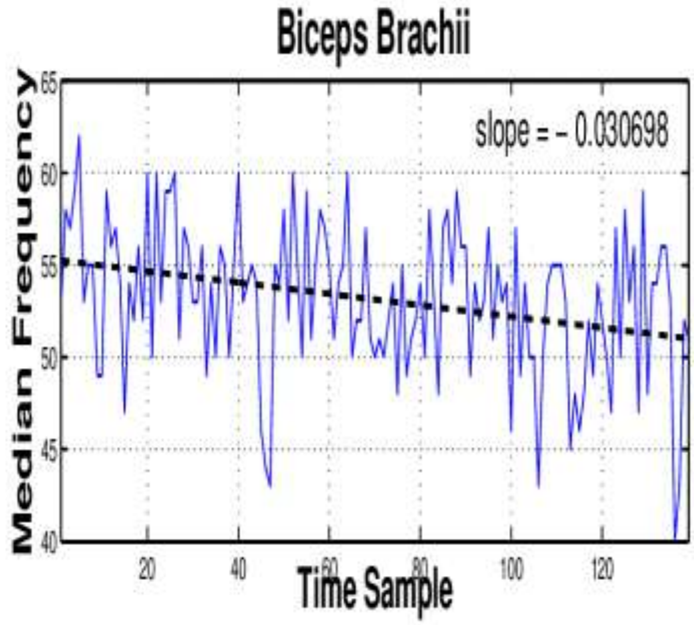

Fig. 6. Decrement of Median frequency of EMG

4. CONCLUSION

We Designed and completed a Muscle fatigue monitoring system based on IoT platform. Here we introduced less power consumption based smart Muscle fatigue monitoring system. It Consists of EMG Sensor with D1 mini board and inbuilt Wi-Fi. Based on the proposed architecture an IoT based Muscle fatigue monitoringsystem was developed. Using wearable monitoring node electrodes, real time EMG signal in isotonic contraction was collected for muscle fatigue detection. The collected data were transmitted to IoT cloud using Wi-Fi. The IoT Cloud is responsible for preprocessing and feature selection of EMG Signal for Detection of muscle fatigue. The EMG features of mean and median frequency are calculated. The GUI based visualization used to visualize extract feature of EMG for the detection of Muscle fatigue in android platform mobile phone.

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