A Mini Project Report on

Muscle Fatigue Evaluation using Accelerometer and EMG

Submitted to the

DEPARTMENT OF
ELECTRONICS AND INSTRUMENTATION ENGINEERING

In partial fulfilment of the requirements of the course

Bachelor of Engineering in Electronics and Instrumentation Engineering

By

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CERTIFICATE

This is to certify that the project work entitled "**Muscle fatigue evaluation using accelerometer and EMG**" is carried out by **Chirag Sinha 1MS19EI014, Aman Verma 1MS19EI003, Guru Manglam Sidhhe 1MS19EI017, Gopal Tyagi 1MS19EI017** are bonafide students of Ramaiah Institute of Technology, Bengaluru in partial fulfilment for the award of Bachelor of Engineering in Electronics and Instrumentation Engineering of Visvesvaraya Technological University, Belagavi during the year 2021-22. It is certified that all corrections/suggestions indicated for Internal Assessment have been incorporated in the report deposited in the department library. The project report has been approved as it satisfies the academic requirements in respect of Project work prescribed for the said degree.

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ABSTRACT

After the outbreak of COVID-19 in 2021 physical contact among people got minimal and everyone avoided the work which required human contact be it Schools, Offices or Gym. People started working from home and also, they tried to keep themselves fit during this tough time by the means of Home Gyms.

The report incorporates fatigue measurement using EMG and accelerometer which will help a user improve their capability to lift heavy weights and save them from muscle injuries without any human contact. The implementation of the hardware has been discussed along with supporting images and block diagrams.

We here focus on counting the repetition of each exercise with the help of an accelerometer and measuring the fatigue using EMG. Furthermore, the scope of work accompanied by its application has been appended in the report.

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INTRODUCTION

We know that the pandemic took an outsize toll on public health and had a far-reaching impact on all business sectors, including the fitness industry. A surge in home-based workouts wasn’t surprising during widespread stay-at-home orders and mandated gym closures in all of the states at the beginning of April. However, now that vaccinations and other safety measures are in place in many areas, fitness clubs have reopened. A majority (80.4%) of consumers polled by Upsell Marketing are open to going back to the gym, and 40% said they’d actually prefer to work out at a gym rather than home — as long as the space felt safe and clean. Nearly half (46.8%) of those surveyed said sanitation is one of the deciding factors for choosing a gym.

Some of the major drawbacks of a home gym are too much flexibility, no accountability and no contact with the Gym Trainer due to which people often overdo themselves and get injured, so to prevent this we are proposing a way which will not require anyone to go to Gym or any contact with Gym trainers or any third person. In this report, we are going to explain how we can use EMG and accelerometer to overcome this issue.

An accelerometer is an instrument used for measuring the acceleration of a moving or vibrating body, it has measure acceleration along 3 axis -X, -Y & -Z respectively so by using the properties of the Accelerometer we can measure the number of repetitions for a particular exercise and it will help us to keep track of each day and by utilising the properties of EMG we can measure the fatigue in the muscle which is under consideration currently by coving these two data a user can know how much exercise is sufficient for the day and can avoid muscle injuries.

Fig 1: Dumbbell pull-up Exercise

1.1 LITERATURE SURVEY

With the help of “M. Ayaz, M. W. Ayub and I. A. Qureshi, "Arduino Based Fatigue Level Measurement in Muscular Activity using RMS Technique” paper concluded that how we can categorize fatigue levels using RMS voltage and BMI.[1]

The "Oliveira AS, Gonçalves M, Cardozo AC, Barbosa FS. Electromyography fatigue threshold of the biceps brachii muscle during dynamic contraction. Electromyography and Clinical Neurophysiology" talks about the results of their research showed a progressive increase in RMS with time, for both brachial muscles in all loads, characterizing the muscle fatigue process.[2]

According to the study of “Oliveira, A. de, & Gonçalves, M. (2009). EMG amplitude and frequency parameters of muscular activity: Effect of resistance training based on electromyographic fatigue threshold” a Journal on Electromyography and Kinesiology we got to know about the improvement in fatigue level of brachial muscle after regular training.[3]

“Bello Salau, Habeeb & Onumanyi, Adeiza & Aibinu, A. & Onwuka, Liz & Dukiya, Jaiye & Ohize, Henry. (2019). A Survey of accelerometer-based Techniques for Road Anomalies Detection and Characterization” this paper deals with the road anomaly detection by the use of the accelerometer in different axes. Each axis gives the corresponding acceleration which later can be converted into distances.[4]

A journal on Computer and Communication by “W.M., Fang, L.Q., Xu, L., Li, X., Huo, R.K., Guo, D.Q. and Qi, Z.Y. (2018) Summary of Research Status and Application of MEMS Accelerometers” tells about why MEMS accelerometer advantages.MEMS Accelerometer is very useful as it is Highly integrated into the system, very light-weighted, and easy to use.[5]

The paper “Full-featured pedometer design realized with 3-axis digital accelerometer. Analog Dialogue” by Zaho, N., 2010 gave us an idea about how we can use the maximum and minimum acceleration values of each axis to count the number of steps for a moving body under a threshold value.[6]

The book “Rep Counter for Weightlifting” by Ryan May helped us to know how we can use uses a Capacitive accelerometer which has a semiconductor material used as pair of beams, when the distance between beams changes the voltage across the capacitor changes.[7]

1.2 SCOPE OF THE WORK

Pre pandemic when things were normal it was easy for people to go to Gym, take the help of gym trainers and continue their exercises but after the pandemic people have avoided human contact as much as possible due to which they have started using a home gym. Now one of the major concerns with home Gym is that one doesn't know how much exercise is enough for the day due to which they injure themselves. We are planning to fill this gap with the help of our project which is Going to count the number of repetitions of the current exercise and also measure the fatigue in the muscle which is currently under consideration and it may help the user to analyse their performance daily and they can keep a record of their exercise and avoid serious injuries. The design is simple enough for any person to implement.

1.3 OBJECTIVES

- To keep a count of each repetition of the exercise currently under consideration
- To notify the user on the basis of a number of current repetitions of the exercise about the level of fatigue they have in the muscle which is divided into two levels: Low fatigue, and High fatigue.

1.4 ORGANISATION OF THE REPORT

This report gives a basic description of how we are going to implement our project and the literature survey included here gives us an idea of how to implement various innovations and overcome the problems that are faced in the development process.

In order to provide an easier understanding of the following project, it has been organized into particular categories. Following are the categories:

- Chapter 1: It includes the basic idea behind selecting the project, literature survey, objectives and scope of work.
- Chapter 2: It consists of a basic introduction to the project and the basic block diagram of the overall system.
- Chapter 3: It explains the hardware and software sections with implementation details.
- Chapter 4: It explains the results obtained from the existing model of the project.
- Chapter 5: This chapter has the conclusion of the projec

CHAPTER 2:

METHODOLOGY

METHODOLOGY

2.1 THEORY:

The basic underlying working principle of an accelerometer is such as a dumped mass on a spring. When acceleration is experienced by this device, the mass gets displaced till the spring can easily move the mass, with the same rate equal to the acceleration it sensed. Then this displacement value is used to measure the acceleration. This technique has been utilized to calculate activity counts by tuning the threshold line position at two-thirds of the range between the minimum and maximum. When the accelerometer data cross the line in a positive direction, one count would be added. After adding each count, a refractory period of 0.5 seconds has occurred to prevent counting another repetition needlessly.

“A typical pattern of x-, y-, and z- measurements corresponding to vertical, forward, and side acceleration of a running person. At least one axis will have relatively large periodic acceleration changes, no matter how the accelerometer is worn, so peak detection and a dynamic threshold-decision algorithm for acceleration on all three axes are essential for detecting a unit cycle of walking or running. The system continuously updates the maximum and minimum values of the 3-axis acceleration every 50 samples. The average value, (Max + Min)/2, is called the dynamic threshold level; this threshold level is used to decide whether steps have been taken. As it is updated every 50 samples, the threshold is dynamic. This choice is adaptive and fast enough.”[Zhao Paper] By using a similar idea we can approach counting the repetition of an exercise.

Measuring muscle activation via electric potential, referred to as electromyography (EMG), has traditionally been used for medical research and diagnosis of neuromuscular disorders. However, with the advent of ever shrinking yet more powerful microcontrollers and integrated circuits, EMG circuits and sensors have found their way into prosthetics, robotics and other control systems. Muscle Sensors are designed to be used directly with a microcontroller. Therefore, our sensors do not output a RAW EMG signal but rather an amplified, rectified, and smoothed signal that will work well with a microcontroller’s analog-to-digital converter (ADC).

2.2 ACCELEROMETER: The accelerometer used in this project is a 3-axis analog accelerometer. The sensor is a low-profile capacitive accelerometer. The mechanical structure, which is made of semiconductor materials, can be modelled as a set of beams attached to a movable central mass that moves between fixed beams. These movable beams move from their stationary position when it experiences acceleration. Essentially, there are 2 variable capacitances, one on each side of the moving beam. The changes in distance between the beams (increasing area for a capacitor) cause changes in the voltage output, which is then used to calculate the acceleration. [BOOK]

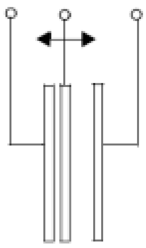


Fig 2.1. Simplified model of accelerometer

The equations for each axes are discussed here,

$$accelerationX = \frac{\frac{accelX * Vref}{1023} - accelXzeroVoltage}{accelSensitivity} \quad \text{-- Equation 1}$$

$$accelerationY = \frac{\frac{accelY * Vref}{1023} - accelYzeroVoltage}{accelSensitivity} \quad \text{-- Equation 2}$$

$$accelerationZ = \frac{\frac{accelZ * Vref}{1023} - accelZzeroVoltage}{accelSensitivity} \quad \text{-- Equation 3}$$

2.3 EMG: Electromyography (EMG) is a diagnostic procedure to assess the health of muscles and the nerve cells that control them (motor neurons). EMG results can reveal nerve dysfunction, muscle dysfunction or problems with nerve-to-muscle signal transmission.

2.4 FUNCTIONAL BLOCK DIAGRAM:

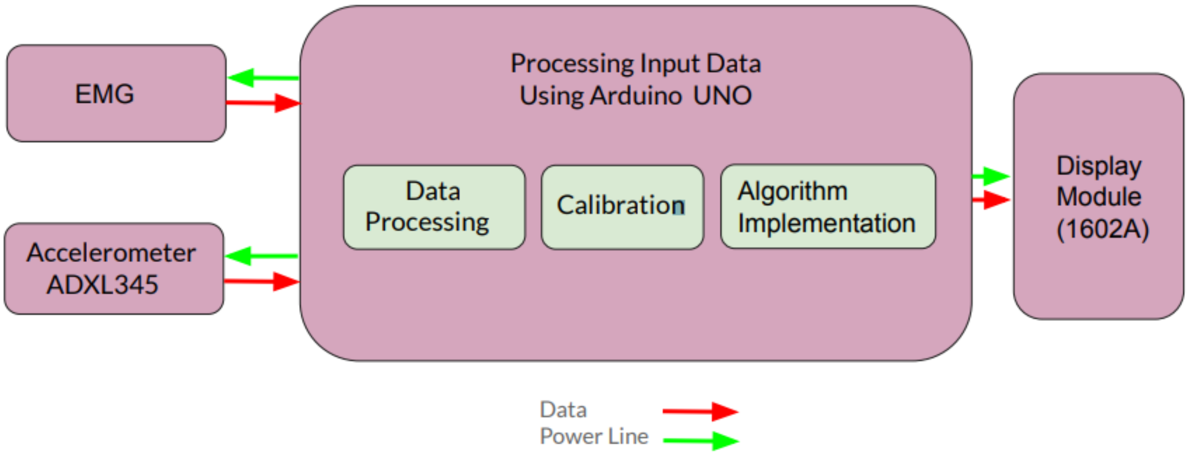


Fig 2.2. Functional Block Diagram

- EMG and Accelerometer signals will be fed to Arduino. Inside the Arduino the processing of those signals will take place. Apart from this, the calibration of the sensors is also done and then finally the algorithm is implemented inside the Arduino itself. Finally, the processed data will be displayed on the display module.

2.5 HARDWARE AND SOFTWARE SELECTION:

Hardware & Software selection

a) ARDUINO UNO
b) ADXL345 Accelerometer
c) Myoware Muscle Sensor V 3.0
d) Sticky pads electrodes
e) Breadboard
f) 16 x 1 LCD Display
g) 9-V Batteries
h) 20 Ohm Resistor

➢ **ADXL345 Accelerometer** Ultra-low-power 25 to 130 µA at VS=2.5 V (Typ)

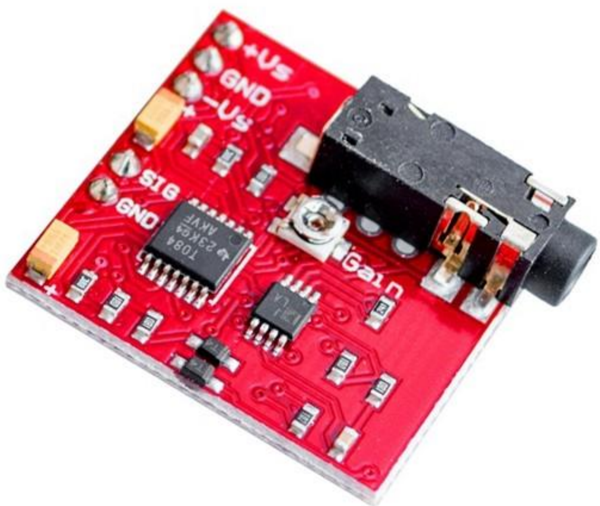
Power consumption scales automatically with bandwidth User-selectable fixed 10-bit resolution or 4mg/LSB scale factor in all g-ranges, up to 13-bit resolution at ±16g 32 level output data FIFO minimizes host processor load. Built-in motion detection functions.

•Tap/Double Tap detection.

•Activity/Inactivity monitoring.

•Free-Fall detection. Supply and I/O voltage range: 1.8 V to 3.6 V. I2C digital interfaces. Wide temperature range (-40 to +85°C). 10,000g shock survival. Small and thin: 3 × 5 × 1 mm.

➢ **Myoware Muscle Sensor V 3.0**



Pin Layout

Parameter	Min	TYP	Max
Power Supply Voltage (Vs)	±3.5V	±5V	±18V
Gain Setting, Gain = 207*(X /1 kΩ)	0.01 Ω (0.002x)	50 kΩ (10,350x)	100 kΩ (20,700x)
Output Signal Voltage (Rectified & Smoothed)	0V	--	+Vs
Differential Input Voltage	0 mV	2-5mV	+Vs/Gain

Electrical Specification

- **Power supply unit:** Two 9V battery is serving as a Power Supply Unit for EMG. For the accelerometer, we need a 5V supply which is given using Arduino and Arduino is given a power supply using a Laptop.

Fig 2.4: Power supply unit.

- **Arduino:** The Arduino board is the brain of the system. The Arduino board receives data from the Accelerometer and EMG, processes the data and sends it to the LCD display. The Arduino typically comes with a USB cord to communicate with a laptop. As mentioned, it can also be powered directly from the computer. Simply attach the cable to the Arduino and your computer.

Fig 2.5: Arduino UNO.

CHAPTER 3:
IMPLEMENTATION

3.1 INTRODUCTION

A simple model to represent the number of counts of repetitions of the current exercise under consideration and to notify them about their fatigue level on the basis of the current repetition count.

3.2 HARDWARE INTERFACING

Our project setup can be broken down into three basic areas:

1) Accelerometer,

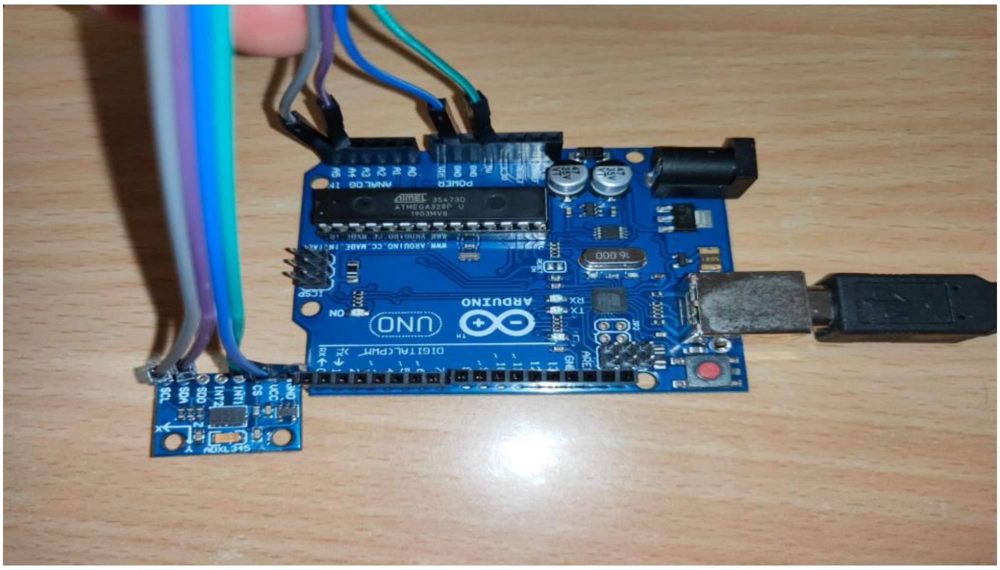
2) Myoware Muscle Sensor v 3.0, and

3) Ardunio interfacing

➢ **Accelerometer**

The ADXL345 accelerometer is used to measure acceleration along three axes which are X-, Y- and Z-. We required the following pin connection to make it work,

- It requires a 5-V voltage supply so, the Vin pin of the accelerometer is connected to the 5-V pin of Arduino.
- The GND pin of the accelerometer is connected to the GND pin of the Arduino.
- The SCL (Secondary Clock Line) pin of the accelerometer is connected to the A4 pin of the Arduino.
- The SDA (Secondary Data Line) pin of the accelerometer is connected to the A5 pin of the Arduino.



As the accelerometer is only giving us the “g” value along each axis so we are considering one particular orientation let's say along Z-axis, now initially “g” will be +10 m/s^2 i.e the hand is currently in the horizontal state which will be changed to 0 m/s^2 i.e the hand is in the middle position and then to -10 m/s^2 then we consider this as one complete repetition.

- **Myoware Muscle Sensor V 3.0**

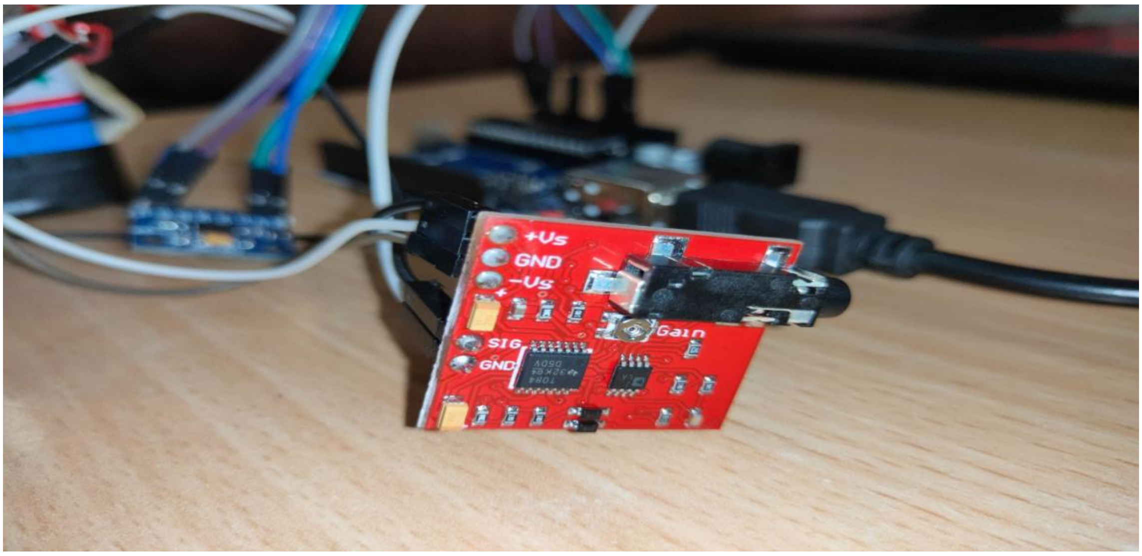
Myoware is used to measure muscle activation via electric potential also referred to as electromyography (EMG), with the advent of ever shrinking yet more powerful microcontrollers and integrated circuits, EMG circuits and sensors have found their way into prosthetics, robotics and other control systems.

We required the following pin layout connection to use Myoware,

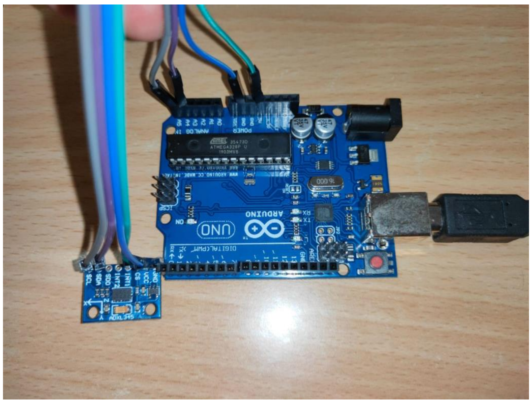
- It requires an 18-V supply so we have connected two 9-V batteries in series along +Vs (+9-V), GND and -Vs (-9-V) pins of Myoware.
- The SIG (signal) pin of the Myoware is connected to the A0 pin of the Arduino.
- The GND (ground) pin of the Myoware is connected to the GND pin of the Arduino.

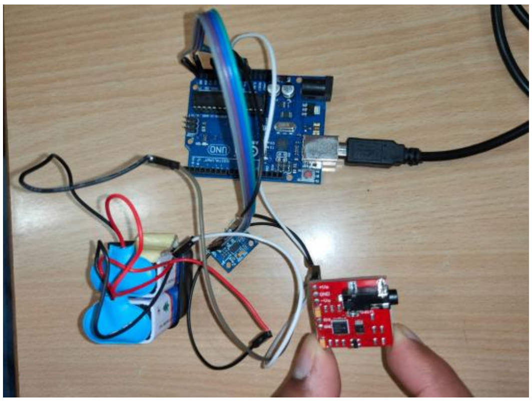
First, we connect the Myoware to the muscle of the subject with the help of sticky pad electrodes. Initially, when the muscle is at rest, the analog input is given to the Myoware as the muscle activity increases the analog input across the Myoware increases.
The Arduino receives analog input from the Myoware it processes that data which is then converted to the digital form and is shown to us, the value varies from 0 to 1023 where 0 means the lowest fatigue level and 1023 means high fatigue value in the active state, so we are dividing this received input from Arduino by 1000 and considering the value is varying from 0 to 1 and using these values we will notify the subject about the fatigue level, following is the scaling which is being considered,

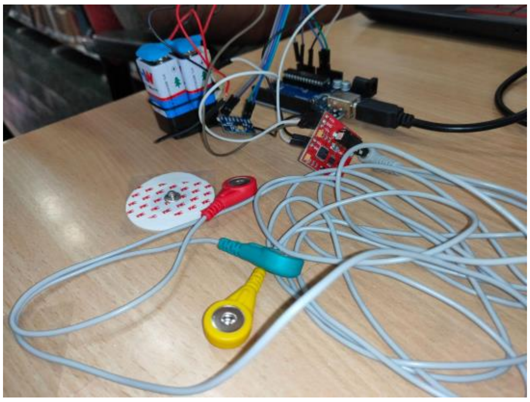
- 0 to 0.5 is considered as low fatigue/No fatigue
- Above 0.5 is considered as high fatigue.

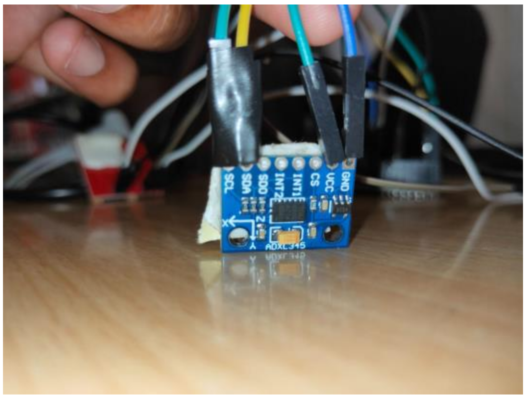


➢ Hardware Connections









3.3 Data Sets:

Name	No. of Repetition	Low fatigue/no fatigue	Fatigue detected
Harshitha	36	0.3-0.40	0.40>=
Ambika	45	0.3-0.47	0.47>=
Hansa	40	0.3-0.44	0.47>=
Gunjan	43	0.3-0.50	0.50>=
Pooja	44	0.3-0.52	0.52>=
Sonal	35	0.3-0.40	0.40>=
Ishita	46	0.3-0.53	0.53>=
Vaishnavi	37	0.3-0.42	0.42>=

Name	No. of Repetition	Low fatigue/no fatigue	Fatigue detected
Abhishek	45	0.3-0.47	0.47>=
Abhay	55	0.3-0.57	0.57>=
Preet	54	0.3-0.51	0.51>=
Parth	60	0.3-0.59	0.59>=
Ritik	48	0.3-0.51	0.51>=
Jai	56	0.3-0.54	0.54>=
Danish	59	0.3-0.59	0.59>=
Prakhar	57	0.3-0.60	0.60>=

CHAPTER 4:

RESULTS

RESULTS

We measured the fatigue and repetition count on different subjects both male and female and the result data set is attached below,

```
rms value in 10 secs is
0.22

rms value in 10 secs is
0.21

rms value in 10 secs is
0.20

rms value in 10 secs is
0.20
```

Fig 4.1 *In this figure the rms value of fatigue is given.*

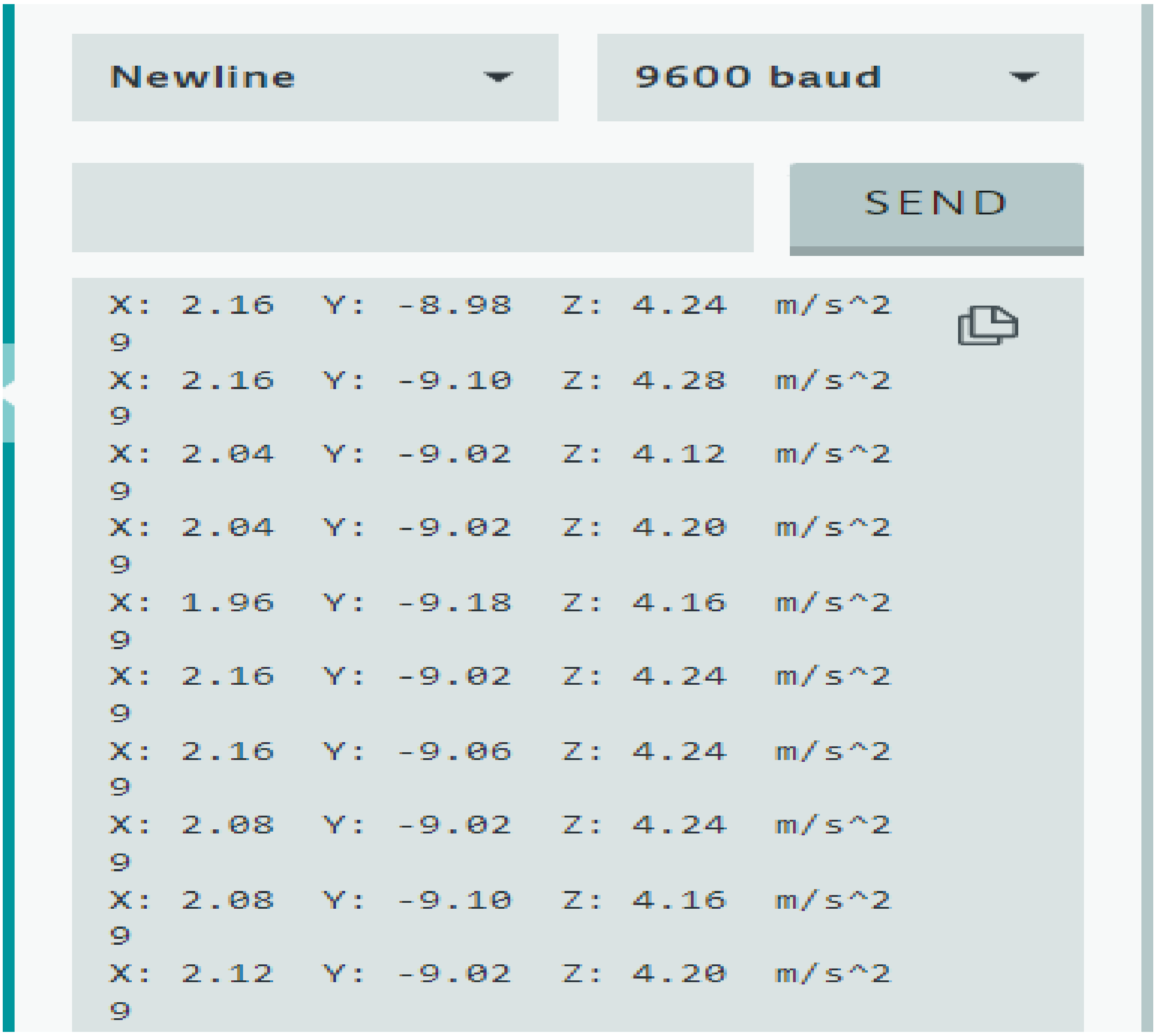


Fig 4.2 *Acceleration Values in X,Y and Z axis.*

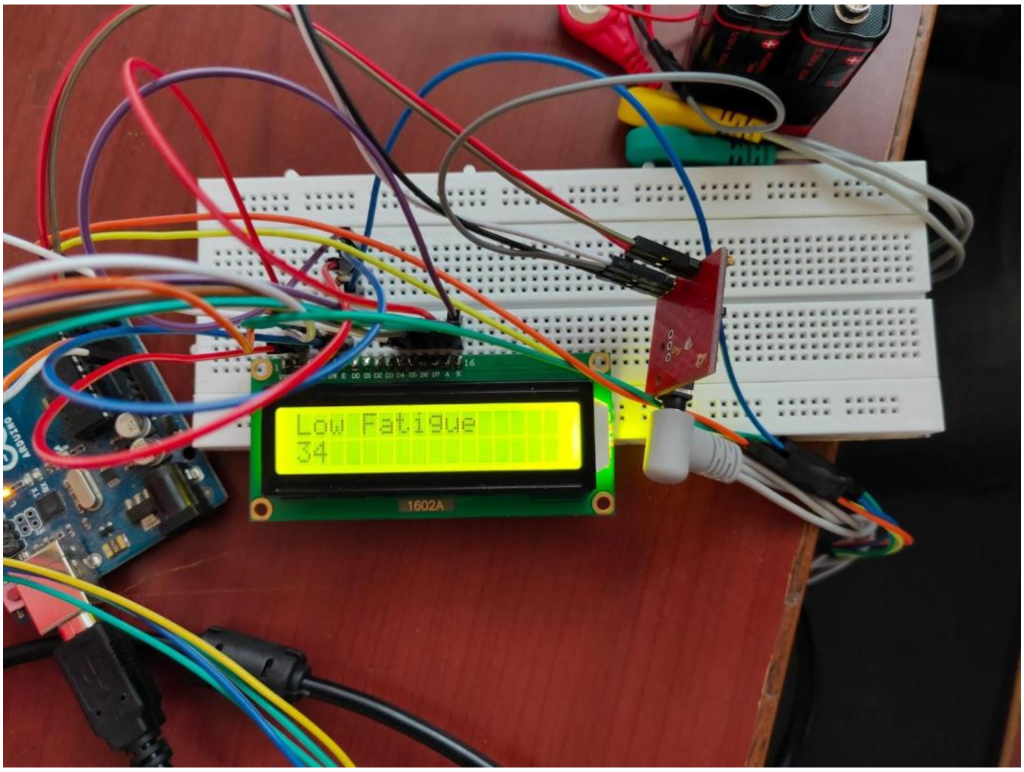


Fig 4.3: *Result Display*

CHAPTER 5:

CONCLUSION

CONCLUSION

- We were able to achieve our first objective of counting the number of repetition of dumbbell lifting exercise for biceps. Accelerometer ADXL 345 sensor gave us appropriate acceleration readings in all the three different axes. With some formulation and techniques for example, by taking the help of orientation change, we were able to come up with a technique to count the number of repetition.

- In Myoware, after doing observation on certain set of people which is in the age group of 19-22 and having BMI less than 25, we are observing that the bicep muscle accumulates lactic acid over it, at that point myoware is giving the average value around 0.45.

  On setting this as threshold we are concluding the bicep muscle got fatigued of the test subject.

CHAPTER 6:

FUTURE SCOPE

FUTURE SCOPE

In today's world, craze of going to gym and doing hard-core exercises is becoming very common. With this there is lot of room for improvement in our project. With ever increasing demand of fitness trainer it is becoming very difficult to get a personal trainer. For this we can try to make our model very modular and compact so that a person can use it in even home with very less technical skills required.

Also this model is restricted for bicep exercise only, so we can extend its use case to other body exercises also. Furthermore, we can work on making the model more accurate and more reliable. As of now we are achieving our target just by feeding a pre-defined algorithm which we developed, but in future we can add some feedback closed loop system with the help of Machine Learning and Artificial Intelligence. We can feedback the real-time data and based on that the model will try to be more accurate and can provide more personal detail about a particular user.

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