

POSTURE ACTIVITIES DETECTION USING A SHOE – BASED WEARABLE SENSOR

Submitted in partial fulfillment of the requirements for the award of Bachelor of
Technology degree in Biomedical Engineering.

By

MONICA S (39240026)

TAMIZHLARRASI R (39240040)



**DEPARTMENT OF BIOMEDICAL ENGINEERING
SCHOOL OF BIO AND CHEMICAL ENGINEERING**

SATHYABAMA

**INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)**

Accredited with Grade “A” by NAAC

JEPPIAAR NAGAR, RAJIV GANDHI SALAI, CHENNAI - 600 119

APRIL - 2023



SATHYABAMA

INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)

Accredited "A" Grade by NAAC | 12B Status by UGC | Approved by AICTE
www.sathyabama.ac.in

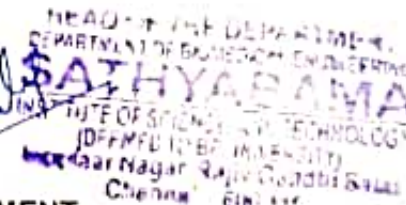
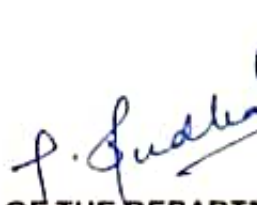
DEPARTMENT OF BIOMEDICAL ENGINEERING

BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of Monica S (39240026), Tamizhlarrasi R (39240040) who carried out the project entitled "Posture activities detection using a shoe-based wearable sensor" under my supervision from October to April 2023.

INTERNAL GUIDE

Ms. A. SABARIVANI, M. Tech., (Ph.D.)



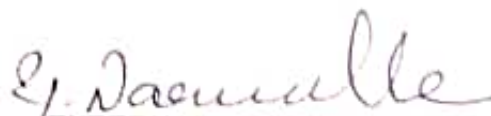
HEAD OF THE DEPARTMENT
DEPARTMENT OF BIOMEDICAL ENGINEERING
SATHYABAMA
INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)
Rajiv Gandhi Salai
Chennai - 600 077

HEAD OF THE DEPARTMENT

Dr. T. SUDHAKAR, M.Sc. Ph.D.

Submitted for Viva voce Examination held on 18.04.2023

INTERNAL EXAMINER

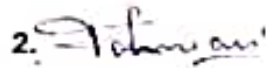


EXTERNAL EXAMINER

DECLARATION

We Monica S (39240026), Tamizhlarrasi R (39240040) here by declare that the Project Report entitled "Posture activities detection using a shoe based wearable sensor" done by us under the guidance of Ms.A.Sabarivani, M. Tech., (Ph.D.) is submitted in partial fulfillment of the requirements for the award of Bachelor of Technology degree in Biomedical Engineering.

1. 

2. 

DATE: 18.04.2023

SIGNATURE OF THE CANDIDATES

PLACE: Chennai

ACKNOWLEDGEMENT

We are pleased to acknowledge our sincere thanks to Board of Management of SATHYABAMA for their kind encouragement in doing this project and for completing it successfully. We are grateful to them.

We convey our thanks Dr.T.Sudhakar, M.Sc. Ph.D., Head of the Department, Biomedical Engineering for providing us necessary support and details at the right time during the progressive reviews.

We would like to express our sincere and deep sense of gratitude to our Project Guide Ms.A.Sabarivani, M.Tech., (Ph.D.) for her valuable guidance, suggestions and constant encouragement paved way for the successful completion of our project work.

We wish to express our thanks to all Teaching and Non-teaching staff members of the Department of Biomedical Engineering who were helpful in many ways for the completion of the project.

We wish to express our sincere thanks to our parents who were helpful and supportive in all ways.

ABSTRACT

Monitoring posture choices and activity levels enables precise energy expenditure estimation and may help with the treatment and prevention of obesity. Since accurate devices now rely on several sensors spread throughout the body, they might be too intrusive for regular use. In this project, we're going to study and analyses using Pedobarography, Dynamic measurements of the pressure distribution on the bottom of the foot throughout all phases of the gait cycle are referred to as "Pedobarography".

We propose a method for identifying postures and gestures using foot pressure sensors, and in order to accurately recognize common postures and activities, we investigate optimal positions for pressure sensors on the inner soles of shoes. And alert the users using haptic feedback, whenever the sensor detects changes in pressure along with this, we plan to log the whole data from the sensors to cloud for future analysis.

Keywords - Biomedical monitoring, energy expenditure, obesity, pattern recognition, posture and activity recognition, wearable devices.

CONTENTS

CHAPTER No.	TITLE	PAGE No.
	ABSTRACT	i
	LIST OF TABLES	v
	LIST OF FIGURES	vi
	LIST OF ABBREVIATIONS	vii
1.	INTRODUCTION	1
	1.1. INTRODUCTION	1
	1.2. PEDOBAROGRAPHY	2
	1.3. GAIT ANALYSIS	2
	1.4. GAIT DISORDERS	3
	1.4.1. Propulsive gait	3
	1.4.2. Scissors gait	3
	1.4.3. Spastic gait	3
	1.4.4. Steppage gait	3
	1.4.5. Waddling gait	4
2.	LITERATURE SURVEY	5
3.	AIM AND SCOPE	12
	3.1. AIM	12
	3.2. SCOPE	12
	3.2.1. Hardware selection and setup	13
	3.2.2. Software development	13
	3.2.3. Calibration	13
	3.2.4. Data collection	13
	3.2.5. Data analysis	13
	3.2.6. Interpretation of results	13
4.	MATERIALS AND METHODS ALGORITHMS USED	14
	4.1. DOMAIN OVERVIEW	14
	4.2. SYSTEM ANALYSIS	15

4.2.1. Existing system	15
4.3. BLOCK DIAGRAM OF WEARABLE SENSOR	15
4.4. HARDWARE REQUIRED	16
4.4.1. ESP 32 microcontroller	16
4.4.1.1. Featured solution	17
4.4.1.2. Features	17
4.4.1.3. Functional block diagram	17
4.4.2. Force sensors	18
4.4.2.1. Size	19
4.4.2.2. Resistance Range	19
4.4.2.3. Force Range	19
4.4.2.4. Power Supply	19
4.4.3. LCD display	20
4.4.3.1. Key features	20
4.4.3.2. Power supply	21
4.4.4. Vibrator	21
4.4.4.1. Internal structure components	22
4.4.4.2. Types	22
4.4.4.2.1. Bar – type vibration motor	22
4.4.5. BC 547 transistor	23
4.4.5.1. Pin configuration of BC547	23
4.4.5.2. Working states	23
4.5. SOFTWARE REQUIRED	24
4.5.1. Arduino IDE	24
4.5.2. Writing sketches	24
4.5.1.1. NB (Narrow band)	24
4.5.3. Sketches	25
4.5.4. Sketches book	25
4.5.5. Libraries	26
4.5.6. Third party hardware	26

	4.5.7. Serial monitor	26
	4.6. ALGORITHM	27
	4.6.1. Fuzzy logic	27
	4.6.2. Architecture diagram of Fuzzy Logic	27
	4.6.3. Implementation of fuzzy logic in Arduino	28
	4.6.4. Advantages and disadvantages	29
	4.6.4.1. Advantages	29
	4.6.1.2. Disadvantages	29
5.	RESULTS AND DISCUSSION	30
	5.1. PROPOSED METHOD	30
	5.1.1. Haptic feedback	30
	5.1.1.1. Tactile haptic feedback	31
	5.1.1.2. Kinesthetic haptic feedback	31
	5.2. RESULT ANALYSIS	31
	5.2.1. Thingspeak IOT cloud platform	32
	5.2.1.1. Graphical representation	33
	5.2.1.2. Mobile application	35
	5.2.1.3. Excel sheet format	39
	5.2.2. LCD display system	41
	5.3. PERFORMANCE AND APPLICATION	41
	5.3.1. Performance	41
	5.3.2. Application	42
6.	SUMMARY AND CONCLUSION	43
	REFERENCES	
	APPENDIX	

LIST OF TABLE

Table No.	Table Name	Page No.
5.1	Excel Sheet of Data Analysis	39

LIST OF FIGURES

Figure No.	Figure Name	Page No.
4.1	Block Diagram of wearable sensor	15
4.2	ESP 32 Microcontroller	16
4.3	Functional Block Diagram of ESP 32 microcontroller	17
4.4	Layers Of FSR	18
4.5	Force Sensors	19
4.6	LCD Display	20
4.7	Vibration Motor	21
4.8	Bar – Type Vibration Motor	22
4.9	Pin Configuration of BC547	23
4.10	Architecture Diagram of Fuzzy Logic	27
5.1	Over all View of The Project	31
5.2	Components connected in the circuit board	32
5.3	Graphical data of front sensor 1 and 2	34
5.4	Graphical Data of front sensor 3 and 4	34
5.5	Graphical Data of back sensor	35
5.6	Mobile Application Data of front sensor 1and 2	36
5.7	Mobile Application Data of front sensor 3 and 4	37
5.8	Mobile Application Data back sensor	38
5.9	LCD Display Data	41

LIST OF ABBREVIATIONS

ADC	- Analog to Digital Converter
AI	- Artificial Intelligent
ANN	- Artificial Neural Network
BMS	- Battery Management System
BSS	- Basic Service Set
CP	- Cerebral Palsy
CPU	- Central Processing Unit
DCF	- Distributed Control System
EMG	- Electromyography
FOG	- Full Outturn Guarantee
FPGA	- Field Programmable Gate Array
FLC	- Fuzzy Logic Controller
FSR	- Force Sensor
GRF	- Ground Reactive Force
HAR	- Human Activity Recognition
IDE	- Integrated Development Environment
IMUs	- INERTIAL Measurement Units
IOT	- Internet Of Things
LCD	- Liquid Crystal Display
MCU	- Micro – Controller Unit
NB	- Narrow Band
OP	- Out Patient
QNAP	- Quality Network Appliance Provider
RF	- Random forests
RGB	- Red-Green-Blue
TCP/IP	- Transmission Control Protocol / Internet Protocol

CHAPTER – 1

INTRODUCTION

1.1. INTRODUCTION

Pedobarography (Karolina Gawronskathe, et. al., 2021) art of measuring and analyzing the pressure forces that the foot exerts on the ground throughout a walking cycle. Wearable pedobarography is a very promising research area, and it is anticipated that its findings will have an impact on a number of healthcare applications, including activity monitoring, gait biometrics, prosthetics, weight estimation, Parkinson's disease (Hubble RP, et. al., 2015), obesity control, physical therapy neuro-motor disorders, and sports medicine. Other engineering disciplines including security, robotics, and entertainment should benefit from wearable pedobarography (Lee. R, et. al., 2021). In the particular context of healthcare applications, it is widely recognized that a number of physical, mental, and emotional health issues are connected with short-term body weight shift patterns.

Researchers employed optimization to precisely position single Flexi-Force pressure sensors (Nagaraj Hegde, et. al., 2018) inserted into shoes beneath the foot. Due to individual differences in gait and foot characteristics, these optimizations cannot be consistently generalized. In a comparative examination of footwear-based wearable systems, other techniques that use integrated sensors for gait analysis and possibly weight estimation are included. These methods, while creative, do not accurately collect (Rinki Gupta, et. al., 2020) the total ground reaction force (GRF) or take into consideration the numerous causes of measurement noise and inaccuracy.

The gait of a person (Jonathan Kofman,et. al., 2019) is how they walk. In order to propel the body forward while walking, balance and muscle coordination are needed. This rhythm is known as the stride. There are several factors that could

result in an irregular gait. Typical causes include a degenerative condition (like arthritis), an inner ear problem, a stroke, foot problems, a neurological disorder and Something as basic as uncomfortable shoes. A gait problem is more likely to develop as you become older since older people tend to have more disorders that lead to aberrant gaits and often have weaker muscles, slower reflexes, and less coordinated muscles than younger ones.

1.2. PEDOBAROGRAPHY

Foot disorders (Jacek Lorkowski, et. al., 2021) are an underestimated widespread ailment, particularly in developed societies. Although often neglected as being of little medical importance, foot disorders may be crippling at any age, adversely affect the quality of life, and hinder the musculoskeletal development and socioemotional development of children. Examples are the flat foot or platy podia, one of the commonest disorders, and more serious conditions such as a discrepancy in leg length, causing a differential overload of both legs, which destabilize posture and may lead to disability. The diagnostic methods for foot disorders are not standardized or unified, appear uncertain and troublesome, and are often guided empirically or by healers' experience rather than being evidence-based.

Recent technological developments, including artificial intelligence, nanotechnology, and medical engineering supported by image analysis, have enabled musculoskeletal diagnostics based on biomechanics rather than the anatomy alone. The pedobarography is an examination of lower limbs, foremost of plantar pressure distribution pattern, providing a graphic illustration of results on standing and walking.

1.3. GAIT ANALYSIS

Gait analysis (Hari Prasanth, et. al. 2021) evaluates how the body travels from one location to another, typically during walking or running. Gait analysis (Monica Chhabra, et. al., 2021) looks for any abnormalities in how a person moves. The

complex functions of a person's visual, somatosensory, and vestibular systems combine to form their gait. Postural and gait irregularities can be caused by issues with any of these systems as well as issues with the associated joints. Usually, the gait analysis process (Masataka Yamamoto, et. al., 2022) lasts between two and four hours. For an evaluation to be effective, patients must be able to walk ten steps back-to-back without assistance. Gait and walking abnormalities (Mukhopadhyay. S. C, 2018) can have a variety of causes, including arthritis, neurological illnesses, and even something as basic as poorly fitting shoes. Different therapies are needed for the different gait abnormalities (Shanshan Chen, et. al., 2017).

1.4. GAIT DISORDERS

1.4.1. Propulsive gait

This gait is seen in people with parkinsonism. The head and neck are bowed forward, and the body is rigid and stooped. Steps typically become quicker and shorter.

1.4.2. Scissors gait

The knees and thighs hit or cross in a pattern resembling scissors when walking, giving rise to the name of this gait. It appears as though the individual is squatting because of the flexed hips, pelvis, and legs. Slow and tiny steps are taken. Patients with spastic cerebral palsy frequently walk in this manner.

1.4.3. Spastic gait

Spastic gait (Hegde. N., et. al., 2018) is a kind of walking that is frequently observed in patients with cerebral palsy or multiple sclerosis and is characterized by one leg that is inflexible and dragged in a semicircular motion on the side most affected by chronic muscle tension.

1.4.4. Steppage gait

A walking technique known as "high stepping" in which the foot points downward and lowers while the toes scratch the ground. In addition to peroneal muscle atrophy or

peroneal nerve injury, spinal conditions (such as spinal stenosis or herniated disc) can also cause this sort of gait.

1.4.5. Waddling gait

A waddling, duck-like gait stems from excessive trunk movement. A hip dislocation present from birth or gradual muscle wasting might cause a waddling gait

CHAPTER - 2

LITERATURE SURVEY

Rinki Gupta, et.al. (2020) has described the identification and categorization of various postures in standing and sitting situations are taken into consideration. It is discovered that employing three triaxial accelerometer and gyroscope sensors produces classification accuracy results that are better than those attained with just one or two sensors. The collected features' principal component analysis provides enough separation between the postures under consideration. Support vector machines, multi-layer perceptron, decision trees, and random forests (RF) were the four classifiers utilized; RF generated the highest accuracy. For nine diverse body positions—five sitting postures and four standing postures—performed by seven people, the RF classifier achieves an average classification accuracy of 95.68%.

Qi song Hu, et. al. (2020) has studied about a revolutionary office chair posture identification system that can classify seven different health-related sitting positions. Six flex sensors are used in the system, together with an Analog to Digital Converter (ADC) board, a Spartan-6 Field Programmable Gate Array, and a Machine Learning method comprising a two-layer Artificial Neural Network (ANN) (FPGA). With a floating-point evaluation, the system achieves 97.78% accuracy, while with a 9-bit fixed-point implementation, it achieves 97.43% accuracy. The ANN and the ADC control logic are built with a propagation delay cap of 8.714 nanoseconds. When the sampling rate is 5 samples per second and the clock frequency is 5 MHz, the dynamic power consumption is 7.35 mW.

Slavomir Matuska, et. al. (2020), had said that the system for incorrect seating position detection is proposed and implemented. The smart chair has six flexible force sensors, which are connected to the system by an Internet of Things (IoT) node based on Arduino. The system detects incorrect seating positions and notifies the users. To receive those notifications, we create a mobile application in advance. The

user receives feedback on their sitting position as well as extra statistical information. The data from smart chairs is collected by a private cloud solution from QNAP and is stored in the MongoDB database. We built basic algorithms for processing the sensor data for recognizing incorrect sitting positions. For the entire logic implementation process, we utilized the Node-RED application.

Rajesh P, et. al. (2020) has found the parameters by one of the best open-source software available from the internet and the validation of readings are carried out by comparing the measured parameters with the standard ones from the accessible sources. For example, the normal average walking cadence of a healthy person is 110-115 steps per minute and the cadence measured for subjects here is approximate to the standard value. This gait setup opens up a platform for people to get easy access to the gait lab for checking out their basic gait parameters and those who are worried about the amount they have to spend to get their few gait parameters checked in the fully fledged gait lab.

Deschamps K, et. al. (2020) , has submitted based on examining and defining the effects of particular pathological foot problems, researchers are particularly drawn to the non-invasive nature of pedobarographic data. However, effective clinical application of pedobarographic technology necessitates a high level of methodological and technical expertise. The technological capabilities of pedobarographic technology were summarized in several studies. Additionally, over the past 20 years, methodological knowledge has increased significantly. Therefore, before path mechanical modelling or functional interpretation of foot and lower limb problems can be pursued, two important considerations must be made. The first step is choosing a specific method to analyze the dynamic plantar footprint, and the second is selecting the parameters that will be used to quantify the findings.

Oliveira FP, et. al. (2020), have done the study on a novel computational framework for automatically classifying feet from digital photographs of plantar pressure is presented. It determines whether the foot is left or right while concurrently calculating

the Cavanagh's arch index (AI) and the modified AI, two well-known footprint indices. Utilizing a collection of plantar pressure images from two widely used pedobarographic devices, the framework's accuracy was assessed. The results were excellent, with perfect classification of every foot under examination as left or right and no discernible discrepancies between the footprint indices computed using the computational technique and the conventional manual method. Additionally, the proposed framework's resistance to the acquisition device and different foot orientations was evaluated and found to be reliable.

Nitin Khadane, et. al. (2019) has done the Gait analysis using Arduino and blender integration is a product that can bring gait analysis to runners without the need for expensive, time-consuming laboratory equipment that requires an expert in order to test and analyze. It enhances running performance and potentially prevent injury. Running performance is improved through gait analysis feedback.

Masataka Yamamoto, et. al. (2022) has aimed to clarify the capability of the gait analysis method fusing RGB camera-based pose estimation by OP and an IMU sensor on the foot segment to measure ankle joint kinematics during various gait conditions. We compared temporo-spatial parameters and lower limb joint angles during overground gait under various conditions, as measured by the 3DMC and OP. The results indicated that the proposed methods could measure temporo-spatial parameters and lower limb joint angles in the sagittal plane under various gait conditions. Future studies should include measurements of patients with gait disabilities to verify the practicality of this method in clinical settings.

Monica Chhabra, et. al. (2021) has described about the three-dimensional gait analysis is the gold standard for gait research. It helps us analyze the movement in the three planes simultaneously. Our gait lab has a walkway that is embedded with 16 force platforms with sufficient space for acceleration and deceleration coupled with 6 infrared cameras and two real-time cameras, enabling the recordings of left and right feet to be made simultaneously with each trial recording at least three complete gait

cycles. This is far superior to other labs where there are only one or two force platforms. The system enables us to capture the natural gait pattern at a self-selected pace with minimum errors.

Nagaraj Hegde, et. al (2018) In order to validate this project its usage for tracking physical activity and gait, a unique shoe-based wearable sensor system (pediatric Smart Shoe) was tested on 11 healthy children and 10 children with cerebral palsy. To minimize the impact of orthotics on sensor signals, new data processing methods were created. For the purpose of automatically classifying daily activities, machine learning models were created. On a GAIT Rite mat, reference measurements and the estimated temporal gait parameters from the Smart Shoe data were compared. The average accuracy of activity classification (for sitting, standing, and walking) for children with CP was 95.3%, compared to 96.2% for healthy children, according to leave-one-out cross-validation.

Matthew Bries, et. al. (2016) In this review paper, the advancements in the field of wearable sensors and systems based on footwear are summarized. The target application heavily influences the electronics, sensor technologies, data transmission, and data processing approaches of such wearable devices. As a result, the study critically assesses the advantages of various application scenarios involving footwear-based systems. Gait analysis, plantar pressure measurement, posture and activity classification, prediction of body weight and energy expenditure, biofeedback, navigation, and fall risk applications are some of the application scenarios that were studied. The review also takes into account the footwear's ability to harvest energy. The essay also makes an effort to explain some of the most recent advancements in the subject and the work that will be needed in the future to improve the profession.

Wang Yan, et. al. (2019) has done a survey on wearable sensor modality centered human activity recognition in health care ; Expert Systems with Applications Volume 137, 15 December 2019. This survey intends to give newcomers and researchers to HAR a more thorough introduction. First, they discuss the cutting-edge sensor

modalities used in HAR. With regard to sensors, activities, data pre-processing, feature learning, and classification, they go deeper into the strategies used in each stage of wearable sensor modality-centered HAR, including both conventional and deep learning techniques. In the section on feature learning, we emphasize both manually created features and features that are automatically learnt by deep networks. Additionally, we show systems that integrate wearable and ambient sensor technology, such as camera-based systems and HAR based on ambient sensors. In order to suggest research concerns for additional HAR enhancement, we finally identify the related challenges.

Jonathan Kofman, et. al. (2019) describes and evaluates the current state of the art of FOG detection and prediction using wearable sensors with the goal of guiding future research, identifying knowledge gaps that need to be filled, and outlining difficulties that should be taken into account. In order to find research using wearable sensors to detect or forecast FOG episodes in Parkinson's disease, this review searched the Scopus, PubMed, and Web of Science databases. Following screening, 74 papers were included, of which 68 were FOG detectors, seven were FOG predictors, and one was in both categories. The participants, walking task, sensor type, body position, feature extraction and selection, classification method, detection and prediction performance, and participants' details were all extracted. The findings demonstrated that FOG identification was enhanced by the use of progressively sophisticated machine learning methods and feature sets. Large FOG datasets were scarce, and FOG manifestation was largely individual-specific. Since they offered person-specific tailoring while maintaining model generalization, transfer learning and semi-supervised learning seemed promise for FOG detection and prediction.

JefersonSilva da Rocha, et. al. (2021) has examined the effects of research design information, sample characteristics, and Pilates program elements as mediators of balance and postural results. Until September 30th, 2021, numerous reviewers explored electronic databases to find papers published in English, Spanish, or Portuguese. Adults over the age of 60 who underwent qualifying trials that assessed static or dynamic balance or posture before and after the intervention.

YantaoYu, et. al. (2021) has analyzed prior techniques to gather information about posture for construction workers via 1) summarizing working principles and applications of posture-related data collection in construction management, which shows the extensive use of motion sensors and Red-Green-Blue (RGB) cameras in posture-related data collection. 2) comparing the aforementioned methods based on data quality and feasibility on construction sites, which reveals the reason why motion sensors and RGB cameras have been prevalent in previous studies, and 3) Outlining research gaps for applications and technologies for collecting data linked to posture, as well as suggesting potential avenues for future research.

Lee, R, et. al. (2021) has done the review on the usefulness of upper body kinematics feedback during work or work-related activities is examined along with wearability and a quantification of the device's kinematics. The results imply that WIST may enhance posture but not pain; nevertheless, the strength of this conclusion is constrained by the caliber of the research. The translation of WIST results requires wearability evaluations. To ensure methodological reproducibility, minimum reporting requirements for WIST should be adhered to.

Shanshan Chen, et. al. (2017) they explore the topic of pervasive gait analysis for medicine using wearable sensors. The review of many types of gait-manifested disorders demonstrates the importance of quantitative gait analysis in clinical diagnosis and treatment, whereas, currently, the expensive and cumbersome laboratory systems limit gait analysis to specialized centers. By reviewing the current methods of using wearable sensors for gait analysis, this paper demonstrates that wearable sensors can replace laboratory gait analysis systems, offering portable, objective, quantitative, continuous, and rich information for gait analysis without imposing constraints on the subjects – hence, providing seamless gait analysis from clinics to the free-living environment. Finally, the issues of applying wearable sensors to clinics are discussed by reviewing the practicality issues and metrics for evaluating measuring instruments, in order to propel wider adoption of wearable sensor-enabled gait analysis, particularly for routine clinical use.

Hegde, N., et. al. (2018) In order to validate its usage for tracking physical activity and gait, a novel shoe-based wearable sensor system (pediatric Smart Shoe) was tested on 11 healthy children and 10 children with CP. To minimize the impact of orthotics on sensor signals, novel data processing methods were created. To automatically categorize daily activities, machine learning models were created. On a GAIT Rite mat, reference measures and the temporal gait parameters predicted from the Smart Shoe data were compared. The average accuracy of activity classification (for sitting, standing, and walking) for children with CP was 95.3%, compared to 96.2% for healthy children, according to a leave-one-out cross-validation procedure. Gait cycle, stance, swing, step time, percentage of single support time on both lower limbs, and cadence average relative errors in gait parameter estimate ranged from 0.2% to 6.4% (standard deviation range = 1.4%-9.9%). These findings indicate that the pediatric Smart Shoe may be utilized for ambulatory monitoring and for measuring the physical activity and gait of children with cerebral palsy.

R. C. Ailneni, et. al. (2019) The purpose of this study was to assess how the wearable posture sensor affected office workers' posture and physical demands on their head and neck. In both the sitting and standing positions, 19 individuals typed using the wearable sensor and without it. During the experiment, they were permitted to modify their workstation using a psychophysical approach. Measurements were made of the head and neck's flexion angles, the gravitational moment on the neck, and the components' placements at the workstation. In comparison to participants who wore a wearable sensor, people with the sensor had, on average, 8% lower neck flexion angles and 14% lower gravitational forces on the neck. When compared to sitting at a desk, having a standing workstation had a greater impact on the wearable sensor's ability to reduce neck postural stress. The wearable posture sensor may be a useful tool for reducing neck postural stress in an office environment.

CHAPTER – 3

AIM AND SCOPE

3.1. AIM

The aim of this project is to design and develop a gait analysis system using an ESP32 microcontroller and force sensors that can provide valuable insights into human locomotion. The system will be designed to collect and process data from force sensors, which will measure the forces exerted on the ground during each step. The data collected will be analyzed using software to identify patterns or abnormalities in the gait data.

3.2. SCOPE

The scope of the project includes selecting appropriate hardware components, such as an ESP32 microcontroller board and force sensors, and setting them up correctly. The software will be developed to collect and process data from the force sensors, and algorithms will be developed to analyse the data. The system will be calibrated using known weights to ensure accurate and reliable data collection. Data will be collected from people walking, recording the forces exerted on each foot, step duration, step length, and other relevant parameters. The collected data will then be analysed using software such as MATLAB or Python to identify patterns or abnormalities in the gait data. Finally, the results will be interpreted in the context of the problem being addressed, considering the limitations of the system and potential sources of error.

The project has the potential to contribute to the development of low-cost and effective gait analysis systems, which can be used to improve the diagnosis and treatment of gait-related conditions. The system can provide valuable information for researchers, clinicians, and physical therapists who are interested in studying human locomotion and identifying abnormalities or changes in gait. The project scope is

relevant to a wide range of applications, including evaluating rehabilitation programs, tracking changes in gait over time, and identifying gait abnormalities in specific populations.

The scope of the project includes the following:

3.2.1. Hardware selection and setup

Selecting the appropriate ESP32 microcontroller board and force sensors, and setting them up correctly.

3.2.2. Software development:

Writing software to collect and process data from the force sensors, and developing algorithms to analyse the data.

3.2.3. Calibration

Calibrating the system using known weights to ensure accurate and reliable data collection.

3.2.4. Data collection

Collecting data from people walking, recording the forces exerted on each foot, step duration, step length, and other relevant parameters.

3.2.5. Data analysis

Analysing the data collected using software such as Python to identify patterns or abnormalities in the gait data and storing the data in IoT Platform.

3.2.6. Interpretation of results

Interpreting the results in the context of the problem being addressed, considering the limitations of the system and potential sources of error.

CHAPTER – 4

MATERIALS AND METHODS ALGORITHMS USED

4.1. DOMAIN OVERVIEW

In this work, we are using Esp32 Microcontroller as the brain of our Project which is programmed by Embedded 'C' Language, as the input of the project we are going to use a total of 6 force sensors, where four Force sensors are mounted on the Front part of the shoe and two sensors are placed on the rear side of the inner sole to measure the force applied, and vibration motors are integrated in the project to provide haptic-feed back to the user and to store the data in the cloud we are Wi-Fi module which is in built in the ESP 32 Microcontroller.

All the data's will be stored in the thingspeak IoT Cloud platform where the data can be visualized in two formats, one is the Graphical Representation and another one is the Excel sheet where all the data are stored which could be used to evaluate the recovery process, LCD Display is connected to view the data through offline mode, even if there is no internet access, we will be able to monitor the data through LCD display.

To power up the whole module we are using battery and to support the power system we will be using Dc-Dc Booster Module along with that BMS (Battery Management System) is used.

To program the whole Module, we will be using Arduino IDLE Software to implement our code which will be programmed using Embedded 'C' Language and to view the data in the cloud we will be using Thingspeak IoT Cloud Platform.

4.2. SYSTEM ANALYSIS

4.2.1. Existing System

Researchers have used optimization to suitably place shoe-integrated single Flexi-Force pressure sensors under the feet. However, such optimizations cannot be reliably generalized due to person-to-person gait and foot variabilities. A comparative study of footwear-based wearable systems lists several other approaches where shoe-integrated sensors are used for gait analysis and possibly also for weight estimation. However, these approaches, while innovative, do not accurately collect the total ground reaction force (GRF), nor do they account for the various sources of measurement noise and error.

4.3. BLOCK DIAGRAM OF THE WEARABLE SENSOR

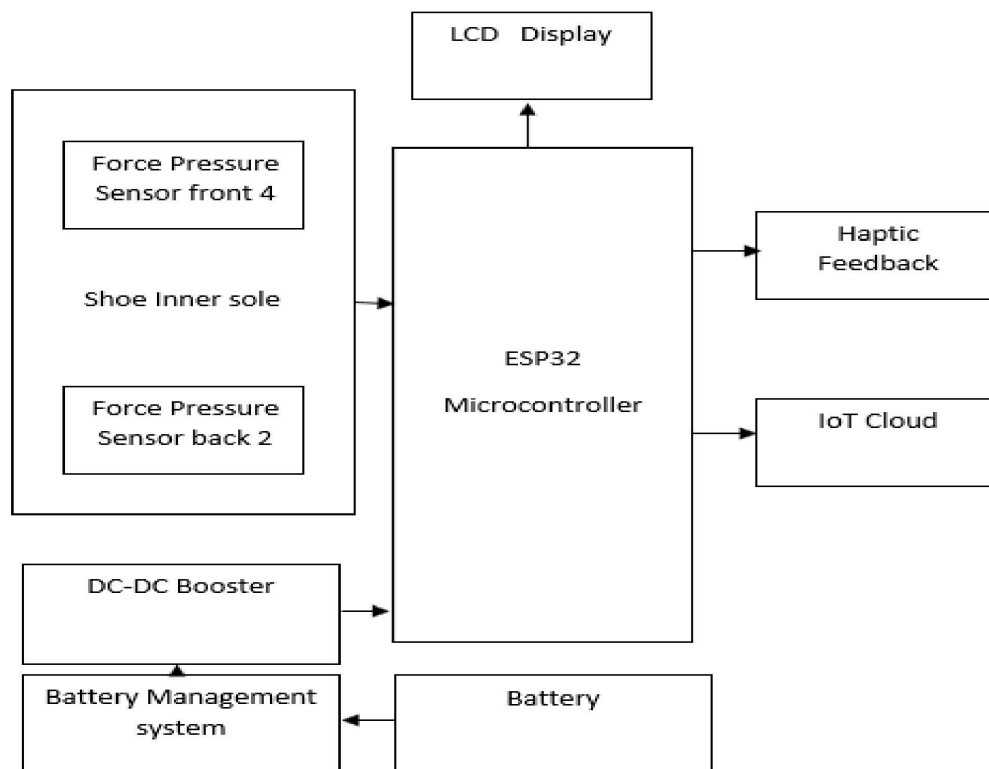


Fig: 4.1: Block Diagram of the wearable sensor

Fig:4.1. shows the block diagram of wearable sensor. The force sensors mounted on the insole is connected to the ESP 32 Microcontroller as an input source and the haptic feedback is the output which provides the vibration through vibration motor. The whole setup is powered by the BMS, the data is stored in the IOT cloud platform. The pressure values are displayed in the LCD display.

4.4. HARDWARE REQUIRED

4.4.1. ESP 32 Microcontroller

ESP32 is a single 2.4 GHz Wi-Fi-and-Bluetooth combo chip designed with the TSMC ultra-low-power 40 nm technology. (Shown in Fig:4.2) It is designed to achieve the best power and RF performance, showing robustness, versatility and reliability in a wide variety of applications and power scenarios.

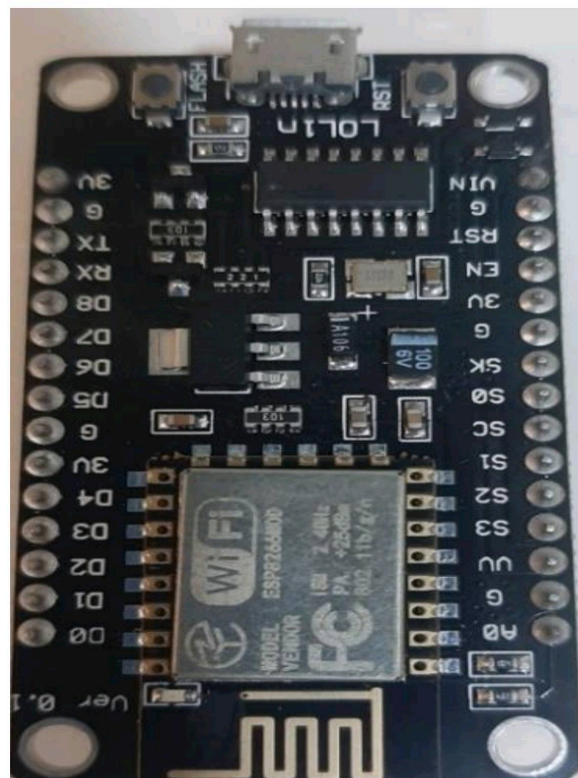


Fig:4.2: ESP 32 Microcontroller

4.4.1.1. Featured solutions

- Ultra – low power Solution
- Complete Integrated Solution

4.4.1.2. Features

- Build in wi-fi: ESP32 implements a TCP/IP and full 802.11 b/g/n Wi-Fi MAC protocol. It supports the Basic Service Set (BSS) STA and Soft AP operations under the Distributed Control Function (DCF). Power management is handled with minimal host interaction to minimize the active-duty period.
- Bluetooth: The chip integrates a Bluetooth link controller and Bluetooth baseband, which carry out the baseband protocols and other low-level link routines, such as modulation/demodulation, packet processing, bit stream processing, frequency hopping, etc.
- MCU and advanced features like CPU and memory, Clock and timers, security, advanced peripheral interfaces.

4.4.1.3. Functional Block Diagram of ESP32 microcontroller

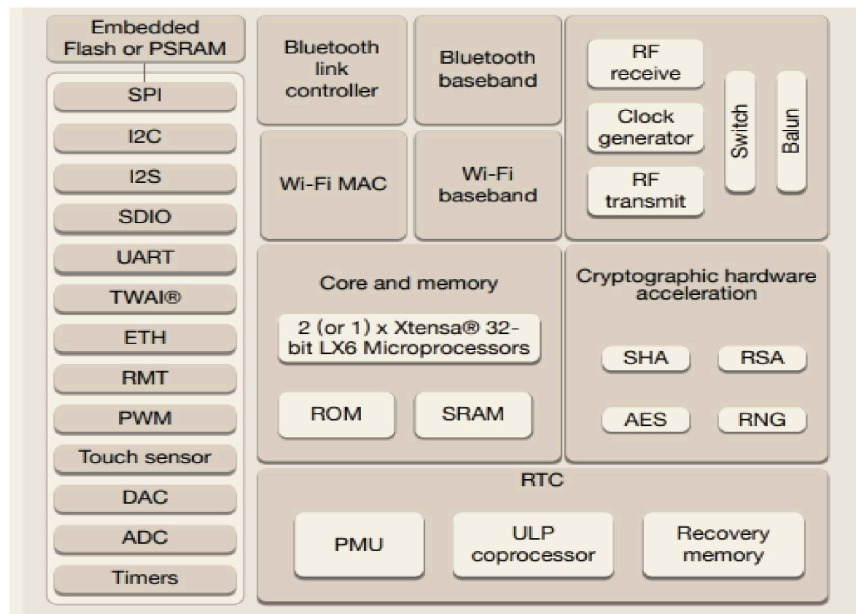


Fig:4.3: Functional block diagram of ESP32 microcontroller

Fig:4.3: represents the functional block diagram of ESP 32 Microcontroller which has inbuilt function of wi-fi and Bluetooth and storage space etc.

4.4.2. Force Sensors (FSR)

FSRs (Ishaku, 2019) are sensors that allow you to detect physical pressure, squeezing and weight. They are simple to use and low cost. This is a photo of an FSR, specifically the Interlink 402 model. The 1/2" diameter round part is the sensitive bit.

The FSR is made of 2 layers separated by a spacer (as shown in Fig: 4.4). The more one presses, the more of those Active Element dots touch the semiconductor and that makes the resistance go down.

FSRs are basically a resistor that changes its resistive value (in ohms Ω) depending on how much it is pressed. These sensors are fairly low cost, and easy to use but they're rarely accurate (Shahzad Muzaffar, et. al., 2020). They also vary some from sensor to sensor perhaps 10%. So basically, when you use FSRs you should only expect to get ranges of response. While FSRs can detect weight, they're a bad choice for detecting exactly how many pounds of weight are on them.

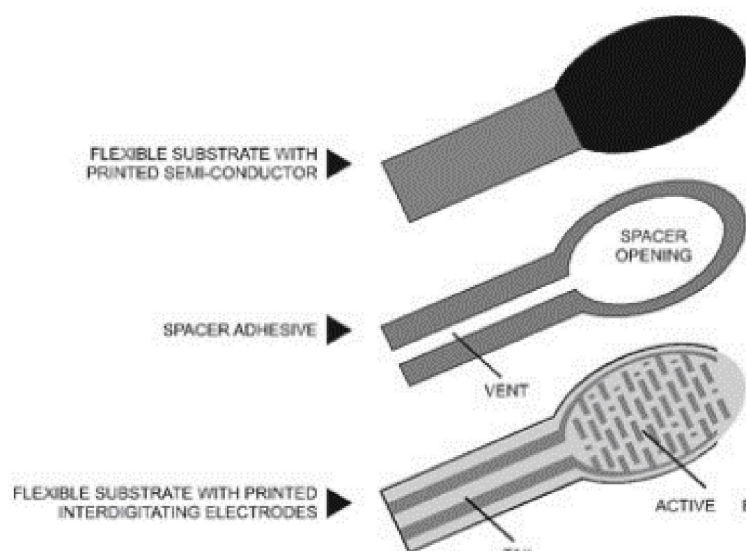


Fig:4.4: Layers of FSR

4.4.2.1. Size:

1/2" (12.5mm) diameter active area by 0.02" thick (Interlink does have some that are as large as 1.5"x1.5").

4.4.2.2. Resistance range:

Infinite/open circuit (no pressure), 100K Ω (light pressure) to 200 Ω (max. pressure).

4.4.2.3. Force range:

0 to 20 lb. (0 to 100 Newtons) applied evenly over the 0.125 sq in surface area.

4.4.2.4. Power supply:

Uses less than 1mA of current, depends on any pullup/down resistors used and supply voltage.



Fig: 4.5: Force sensors

Fig: 4.5 shows the real time image of force sensor which is used in this project. We have used 6 force sensors in total where 4 sensors are mounted on the front side and 2 on the back side of the insole

4.4.3. LCD Display

Liquid crystal displays (LCDs) have materials which combine the properties of both liquids and crystals, Fig: 4.6. Rather than having a melting point, they have a temperature range within which the molecules are almost as mobile as they would be in a liquid, but are grouped together in an ordered form similar to a crystal.

An LCD consists of two glass panels, with the liquid crystal material sandwiched in between them. The inner surface of the glass plates is coated with transparent electrodes which define the character, symbols or patterns to be displayed. Polymeric layers are present in between the electrodes and the liquid crystal, which makes the liquid crystal molecules to maintain a defined orientation angle.



Fig:4.6: LCD Display

4.4.3.1. Key features

- The LCDs are lightweight with only a few millimeters thickness. Since the LCDs consume less power, they are compatible with low power electronic circuits, and can be powered for long durations.
- The LCDs don't generate light and so light is needed to read the display. By using backlighting, reading is possible in the dark. The LCDs have long life and a wide operating temperature range.
- Changing the display size or the layout size is relatively simple which makes the LCDs more customer friendly.

4.4.3.2. Power supply

The power supply should be of +5V, with maximum allowable transients of 10mv. To achieve a better / suitable contrast for the display, the voltage (VL) at pin 3 should be adjusted properly.

A module should not be inserted or removed from a live circuit. The ground terminal of the power supply must be isolated properly so that no voltage is induced in it. The module should be isolated from the other circuits, so that stray voltages are not induced, which could cause a flickering display.

4.4.4. Vibration Motor

Vibration motor, shown in Fig: 4.7 is a compact size coreless DC motor used to inform the users of receiving the signal by vibrating, no sound. Vibration motors are widely used in a variety of applications including cell phones, handsets, pagers, and so on. The main features of vibration motor are the magnet coreless DC motor are permanent, which means it will always have its magnetic properties, another main feature is the size of the motor itself is small, and thus light weight. Moreover, the noise and the power consumption that the motor produce while using are low. Based on those features, the performance of the motor is highly reliable.

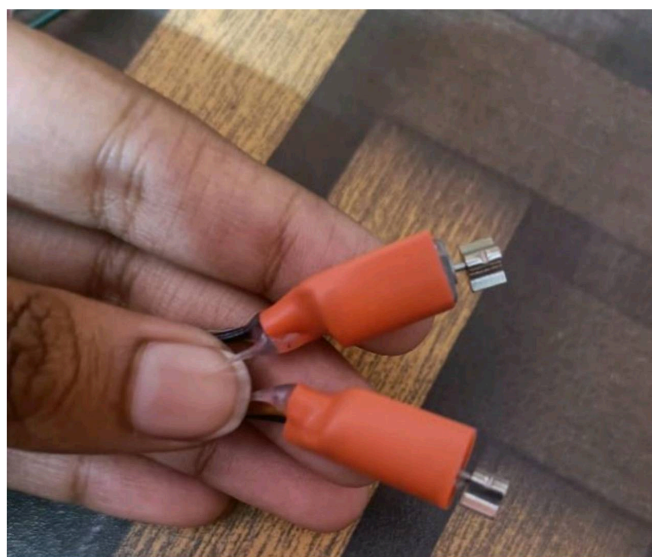


Fig: 4.7: Vibration Motor

4.4.4.1. Internal structure components

- Rotor
- Stator
- Commutator
- Armature
- Windings
- Weight
- Brushes

4.4.4.2. Types

- Bar – type vibration motor
- Coin – type vibration motor

4.4.4.2.1. Bar-type vibration motor

The cylinder shape is also called bar-type vibration motor. This vibrating motor is essentially a motor that is improperly balanced. In other words, there is an off-centered weight attached to the motor's rotational shaft that produces a centrifugal force while rotating. This unbalanced force displaces the motor. Its high-speed displacement makes the motor to wobble, which is known as the “vibrating”. The wobble can be changed by the weight mass you attach, the weight's distance to the shaft, and the speed at which the motor spins.

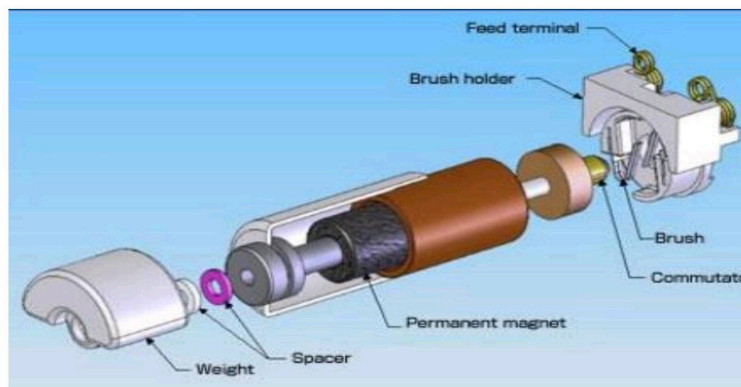


Fig:4.8: Bar-type vibration motor

Fig:4.8 shows the internal structure of a bar-type vibration motor. This type of vibration motor is used in this project.

4.4.5. BC 547 Transistor

The BC547 transistor is an NPN transistor. A transistor is nothing but the transfer of resistance which is used for amplifying the current. A small current of the base terminal of this transistor will control the large current of emitter and base terminals. The main function of this transistor is to amplify as well as switching purposes. The maximum gain current of this transistor is 800A.

4.4.5.1. Pin configuration of BC547

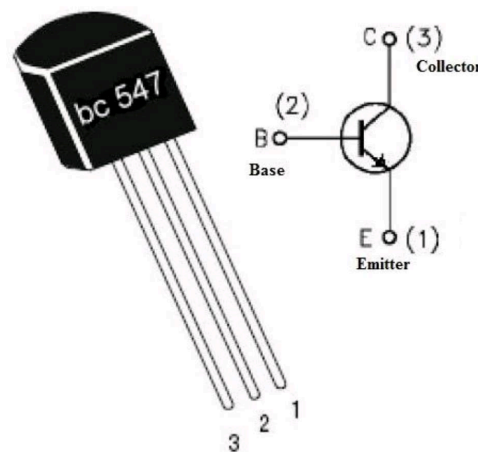


Fig:4.9: Pin configuration of BC547

Fig:4.9 represents the pin configuration of BC 547 transistor where the 3 pins are described as follows

- Pin1 (Collector): This pin is denoted with symbol 'C' and the flow of current will be through the collector terminal.
- Pin2 (Base): This pin controls the transistor biasing.
- Pin3 (Emitter): The current supplies out through emitter terminal

4.4.5.2. Working States

- Forward Bias
- Backward Bias

In a forward bias mode, the two terminals like emitter & collector are connected to allow the flow of current through it. Whereas in a reverse bias mode, it doesn't allow the flow of current through it because it works as an open switch.

4.5 SOFTWARE REQUIRED

4.5.1. *Arduino Integrated Development Environment (IDE)*

Arduino Integrated Development Environment (IDE) v1 Learn how the Arduino IDE v1 works, such as compiling & uploading sketches, file management, installing dependencies and much more.

The Arduino Integrated Development Environment – or Arduino Software (IDE) – contains a text editor for writing code, a message area, a text console, a toolbar with buttons for common functions and a series of menus. It connects to the Arduino hardware to upload programs and communicate with them.

4.5.2. *Writing Sketches*

Programs written using Arduino Software (IDE) are called sketches. These sketches are written in the text editor and are saved with the file extension “.ino”. The editor has features for cutting/pasting and for searching/replacing text. The message area gives feedback while saving and exporting and also displays errors. The console displays text output by the Arduino Software (IDE), including complete error messages and other information. The bottom righthand corner of the window displays the configured board and serial port. The toolbar buttons allow you to verify and upload programs, create, open, and save sketches, and open the serial monitor.

4.5.2.1. *NB (Narrow Band)*

Versions of the Arduino Software (IDE) prior to 1.0 saved sketches with the extension. pde. It is possible to open these files with version 1.0, you will be prompted to save the sketch with the. ino extension on save.

4.5.3. Sketches

Verify/Compile - Checks your sketch for errors compiling it; it will report memory usage for code and variables in the console area.

Upload - Compiles and loads the binary file onto the configured board through the configured Port.

Upload Using Programmer - This will overwrite the bootloader on the board; you will need to use Tools > Burn Bootloader to restore it and be able to Upload to USB serial port again. However, it allows you to use the full capacity of the Flash memory for your sketch. Please note that this command will NOT burn the fuses. To do so a Tools -> Burn Bootloader command must be executed.

Export - Compiled Binary Saves a .hex file that may be kept as archive or sent to the board using other tools.

Show Sketch Folder - Opens the current sketch folder.

Include Library - Adds a library to your sketch by inserting #include statements at the start of your code. For more details, see libraries below. Additionally, from this menu item you can access the Library Manager and import new libraries from .zip files.

Add File - Adds a supplemental file to the sketch. The file is saved to the data subfolder of the sketch, which is intended for assets such as documentation. The contents of the data folder are not compiled, so they do not be part of the sketch.

4.5.4. Sketches Book

The Arduino Software (IDE) uses the concept of a sketchbook: a standard place to store your programs or sketches. The sketches in your sketchbook can be opened from the File > Sketchbook menu or from the Open button on the toolbar. The

first time you run the Arduino software, it will automatically create a directory for your sketchbook. You can view or change the location of the sketchbook location from with the Preferences dialog.

Beginning with version 1.0, files are saved with a .ino file extension. Previous versions use the. pde extension. You may still open. pde named files in version 1.0 and later, the software will automatically rename the extension to. ino.

4.5.5. Libraries

Libraries provide extra functionality for use in sketches, e.g., working with hardware or manipulating data. To use a library in a sketch, select it from the Sketch > Import Library menu. This will insert one or more `#include` statements at the top of the sketch and compile the library with your sketch. Because libraries are uploaded to the board with your sketch, they increase the amount of space it takes up. If a sketch no longer needs a library, simply delete its `#include` statements from the top of your code.

There is a list of libraries in the reference. Some libraries are included with the Arduino software. Others can be downloaded from a variety of sources or through the Library Manager. Starting with version 1.0.5 of the IDE, you do can import a library from a zip file and use it in an open sketch. See these instructions for installing a third-party library.

4.5.6. Third Party Hardware

Support for third-party hardware can be added to the hardware directory of your sketchbook directory. Platforms installed there may include board definitions which appear in the board menu, core libraries, bootloaders, and programmer definitions. To install, create the hardware directory, then unzip the third-party platform into its own sub-directory. To uninstall, simply delete its directory.

4.5.7. Serial Monitor

This displays serial sent from the Arduino board over USB or serial connector. To send data to the board, enter text and click on the "send" button or press enter.

Choose the baud rate from the drop-down menu that matches the rate passed to Serial. Begin in your sketch. Note that on Windows, Mac or Linux the board will reset and it will rerun your sketch when you connect with the serial monitor. Please note that the Serial Monitor does not process control characters; if your sketch needs a complete management of the serial communication with control characters, you can use an external terminal program and connect it to the COM port assigned to your Arduino board.

4.6. ALGORITHMS

4.6.1. Fuzzy Logic

Fuzzy logic is a type of mathematical logic that is used to deal with uncertain or vague information. In a fuzzy logic system, variables can take on any value between 0 and 1, which represents the degree of membership of a particular set. Fuzzy logic can be used in a wide range of applications, including control systems, pattern recognition, and decision-making. In Arduino, fuzzy logic can be implemented using a library called Fuzzy Logic Controller (FLC). This library provides a set of functions and tools that can be used to create fuzzy logic systems for various applications.

4.6.2. Architecture Diagram of Fuzzy Logic

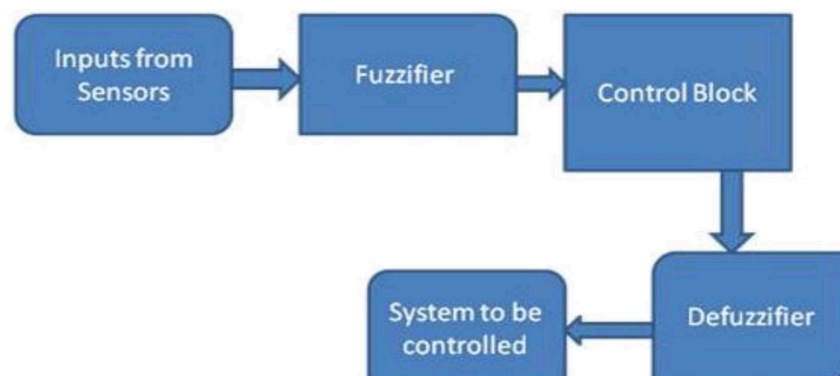


Fig:4.10: Architecture diagram of Fuzzy Logic

Fig: 4.10 shows the architecture diagram of the fuzzy logic used in this project.

The input from the force sensor is sensed and send to the fuzzifier which converts the input values into fuzzy values, then it is passed through the control block, and to the

de-fuzzifier. From the de-fuzzifier it is send to the system which will generate the output (vibration motor).

4.6.3. Implementing Fuzzy Logic in Arduino

The basic steps involved in implementing fuzzy logic in Arduino using the FLC library are:

- In fuzzy logic, the input and output variables are defined in terms of membership functions, which specify the degree of membership of a particular input or output to a particular set. For example, if we are designing a fuzzy logic system to control the speed of a motor, the input variable could be the error between the desired speed and the actual speed, and the output variable could be the motor speed. We would need to define membership functions for both these variables, such as slow, medium, and fast.
- The rules in a fuzzy logic system are used to map the input variables to the output variables. For example, if the error is small, the motor speed should be slow. These rules are defined using if-then statements, such as "if the error is small, then the motor speed should be slow".
- Once the input and output variables and the rules are defined, we can implement the fuzzy logic system using the FLC library. The library provides functions for defining the membership functions, rules, and input-output mappings, as well as tools for simulating and testing the system.
- Finally, we need to tune the system to get the desired performance. This involves adjusting the membership functions and the rules to optimize the system for a particular application.

4.6.4 Advantages and Disadvantages

4.6.4.1. Advantages

- This system can work with any type of inputs whether it is imprecise, distorted or noisy input information.
- The construction of Fuzzy Logic Systems is easy and understandable.
- Fuzzy logic comes with mathematical concepts of set theory and the reasoning of that is quite simple.
- It provides a very efficient solution to complex problems in all fields of life as it resembles human reasoning and decision-making.
- The algorithms can be described with little data, so little memory is required.

4.6.4.2. Disadvantages

- Many researchers proposed different ways to solve a given problem through fuzzy logic which leads to ambiguity. There is no systematic approach to solve a given problem through fuzzy logic.
- Proof of its characteristics is difficult or impossible in most cases because every time we do not get a mathematical description of our approach.

CHAPTER – 5

RESULTS AND DISCUSSION

5.1. PROPOSED SYSTEM

The main purpose of this project is to address the challenges in wearable body weight estimation using a novel approach to shoe-integrated sensor design and characterization. The main sensor design innovation is the integration of force sensors in multi-layered structures that act as force consolidators and channel the total applied force to a set of critically placed points under the foot. The second design innovation is a semi-computational methodology for the fast extraction of transduction characteristics of the sensing layer in the multi-layer structure. If un-even pressure sensed our proposed system will automatically alert the user using haptic feedback.

5.1.1 Haptic Feedback Technology

The study of feeling through touch, known as haptics, is the foundation for how we interact and carry out daily tasks. A glass of water, a keyboard, or even just walking rely on haptics to stimulate the mechanoreceptors through force feedback. Numerous such sensors allow us to move our bodies in any way we like by converting mechanical information into electric signals for our muscles.

This incredibly basic human function is the foundation of haptic technology.

The 18,000 mechanoreceptors in a single hand, which make up 31% of the body's total, are strong instruments that engineers are now taking into consideration when creating tactile electronic displays.

Utilizing physical feedback to replicate tactile experiences is known as haptic technology. This haptic feedback is made possible by software that reacts to human

contact, such as when a video game controller vibrates during specific actions or a smartphone gives off a button-clicking feeling when the user pushes the screen.

Haptic feedback falls into two basic categories:

- Tactile Haptic Feedback
- Kinesthetic Haptic Feedback

5.1.1.1. Tactile Haptic Feedback

The most prevalent sort of haptic feedback is undoubtedly tactile; it describes the vibrations and friction found in mobile devices.

5.1.1.2. Kinesthetic Haptic Feedback

Kinesthetic haptic feedback refers to more sudden physical cues that shift a user's body's posture, such as when a vehicle seat in an arcade game shakes or rumbles as the player navigates a virtual route.

5.2. RESULT ANALYSIS

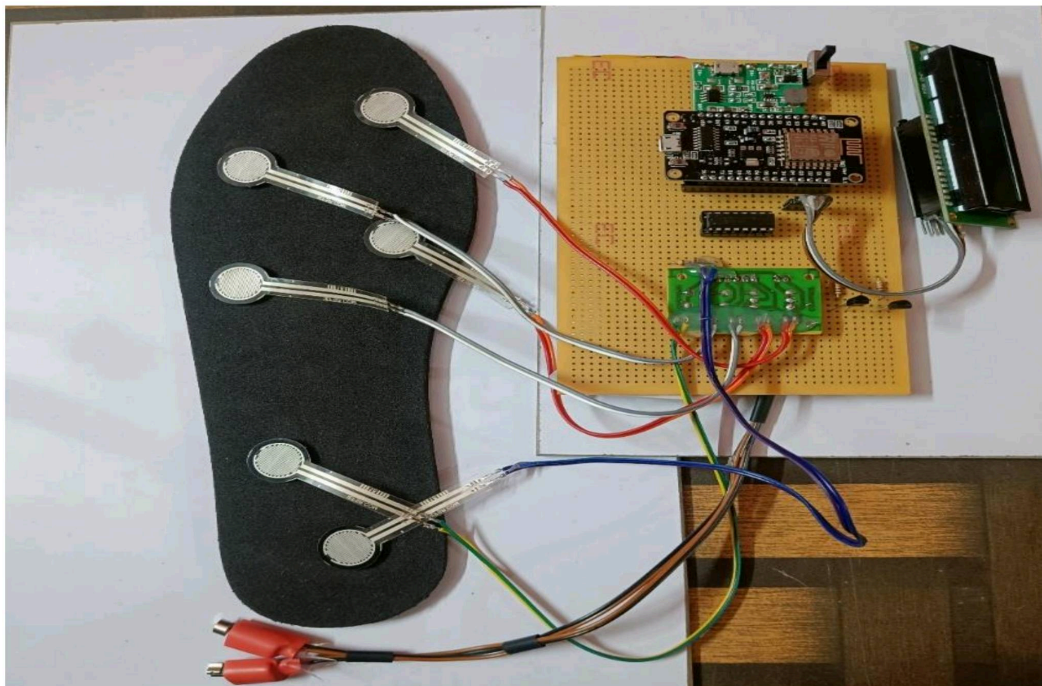


Fig:5.1: Overall view of the project

Fig:5.1 shows the overall view of the project where the force sensors which is placed in the insole of the shoe and other components like microcontroller, LCD display, vibration motor are connected together in the circuit board for the process.

The pressure given on the insole generates the value of pressure applied in the force sensor, which is stored in the IOT cloud space called Thingspeak IOT cloud platform and also in the LCD display connected with the circuit.

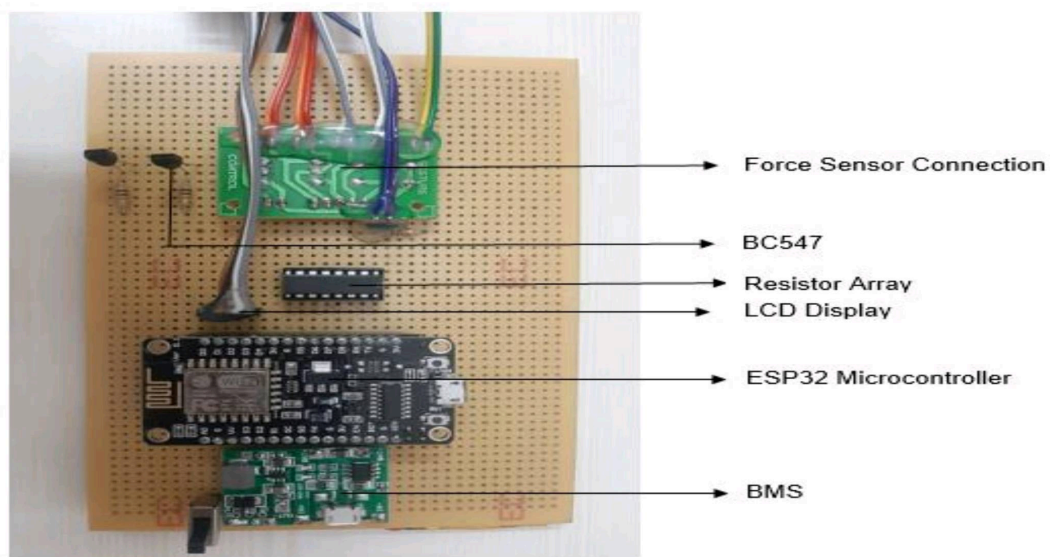


Fig:5.2: Components connected in the Circuit Board

Fig:5.2 explains about the various components used in this project, where it has the ESP32 microcontroller, BMS, BC547, resistor array connected in the circuit board.

5.2.1. Thingspeak IOT Cloud Platform

ThingSpeak is a platform providing various services exclusively targeted for building IoT applications. It offers the capabilities of real-time data collection, visualizing the collected data in the form of charts, ability to create plugins and apps for collaborating with web services, social network and other APIs. We will consider each of these features in detail below.

The core element of ThingSpeak is a 'ThingSpeak Channel'. A channel stores the data that we send to ThingSpeak and comprises of the below elements:

- Eight fields for storing data of any type - These can be used to store the data from a sensor or from an embedded device.
- Three location fields - Can be used to store the latitude, longitude and the elevation. These are very useful for tracking a moving device.
- One status field - A short message to describe the data stored in the channel.

To use ThingSpeak, we need to sign up and create a channel. Once we have a channel, we can send the data, allow ThingSpeak to process it and also retrieve the same. Let us start exploring ThingSpeak by signing up and setting up a channel.

The data which is stored in this platform can be visualized in the following forms

- Graphical Representation
- Mobile Application
- Excel Sheet format

5.2.1.1. Graphical Representation

Graphical representation of the data can be viewed in the Thingspeak IOT cloud platform. The graphical representation of each sensor (six Force sensor) can be viewed separately.

- x axis represents the time at which the pressure is recorded
- y axis represents the pressure value attained by each of the force sensors.

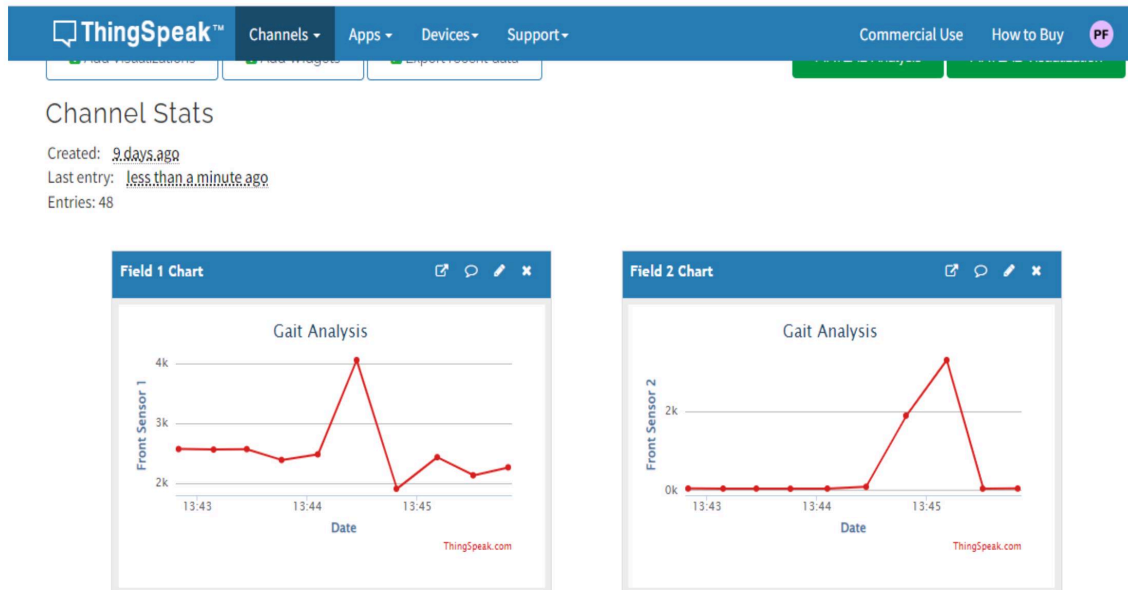


Fig:5.3: Graphical data of front sensor 1 and 2

Fig: 5.3 shows the graphical representation of 1st two force sensors placed at the front side of the insole.

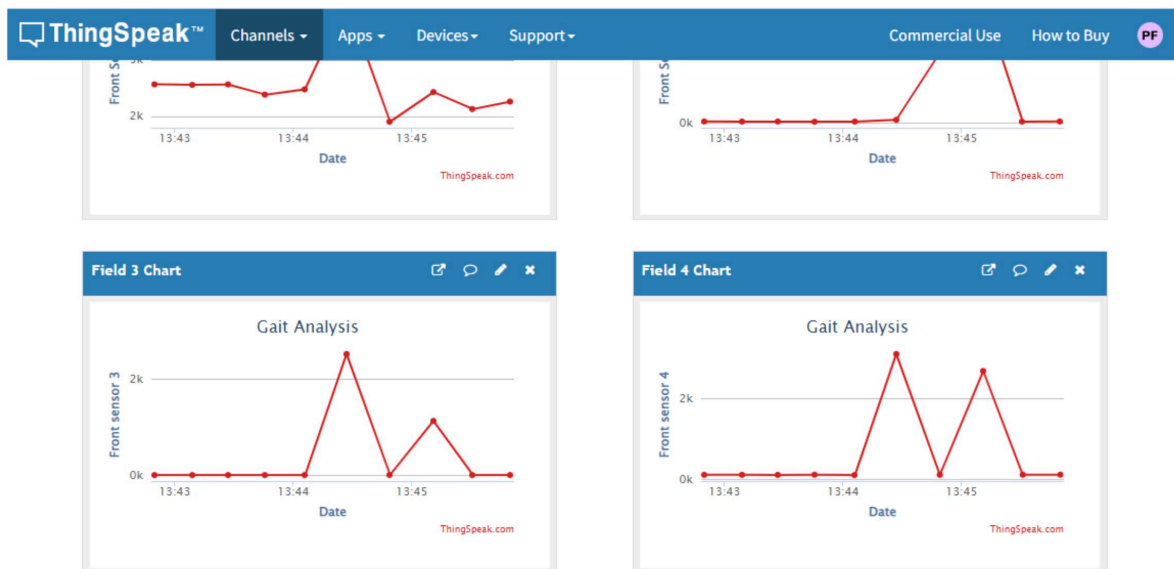


Fig:5.4: Graphical data of front sensor 3 and 4

Fig:5.4 shows the graphical representation of the next two sensors (in front side).

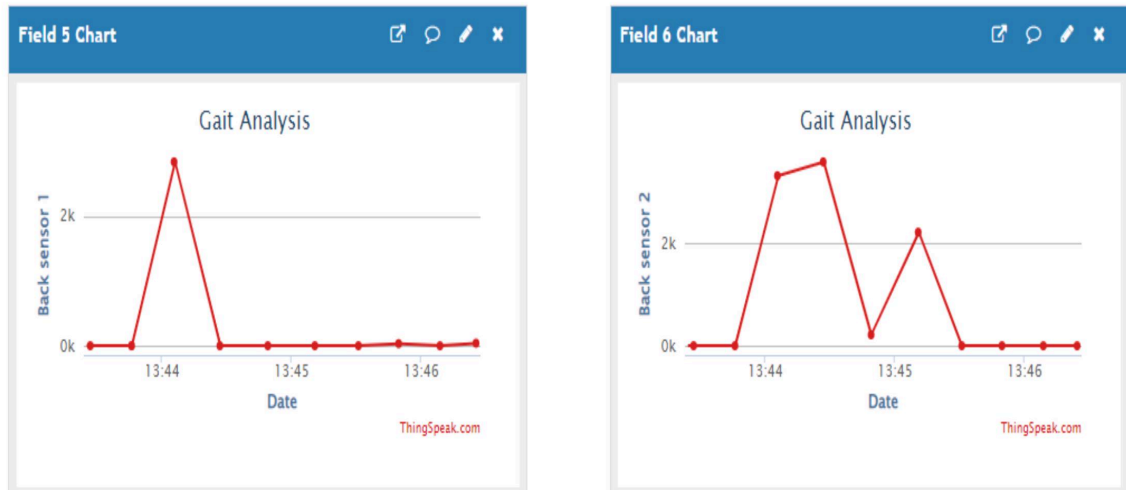


Fig:5.5: Graphical data of back sensors

Fig:5.5 shows the graphical data of the two sensors which is placed on the back side of the insole.

5.2.1.2. Mobile Application

The graphical representation can also be viewed in a mobile through the application called “Thing View”, in which the data can be seen by the user in their mobiles. The doctors can allow the user to view their data at the user place.

- ✓ The x axis represents the time at which the pressure is recorded.
- ✓ The y axis represents the value of the pressure.
- ✓ It also shows the last attained value in that particular sensor.

The following are the screenshot images of the mobile application which provides a graphical data of four front sensors and two back sensors.



Fig:5.6: Mobile application data of front sensor 1 and 2

Fig:5.6 shows the screen shot image of the graphical data displayed on a mobile application. It shows the data of 1st two front sensors.

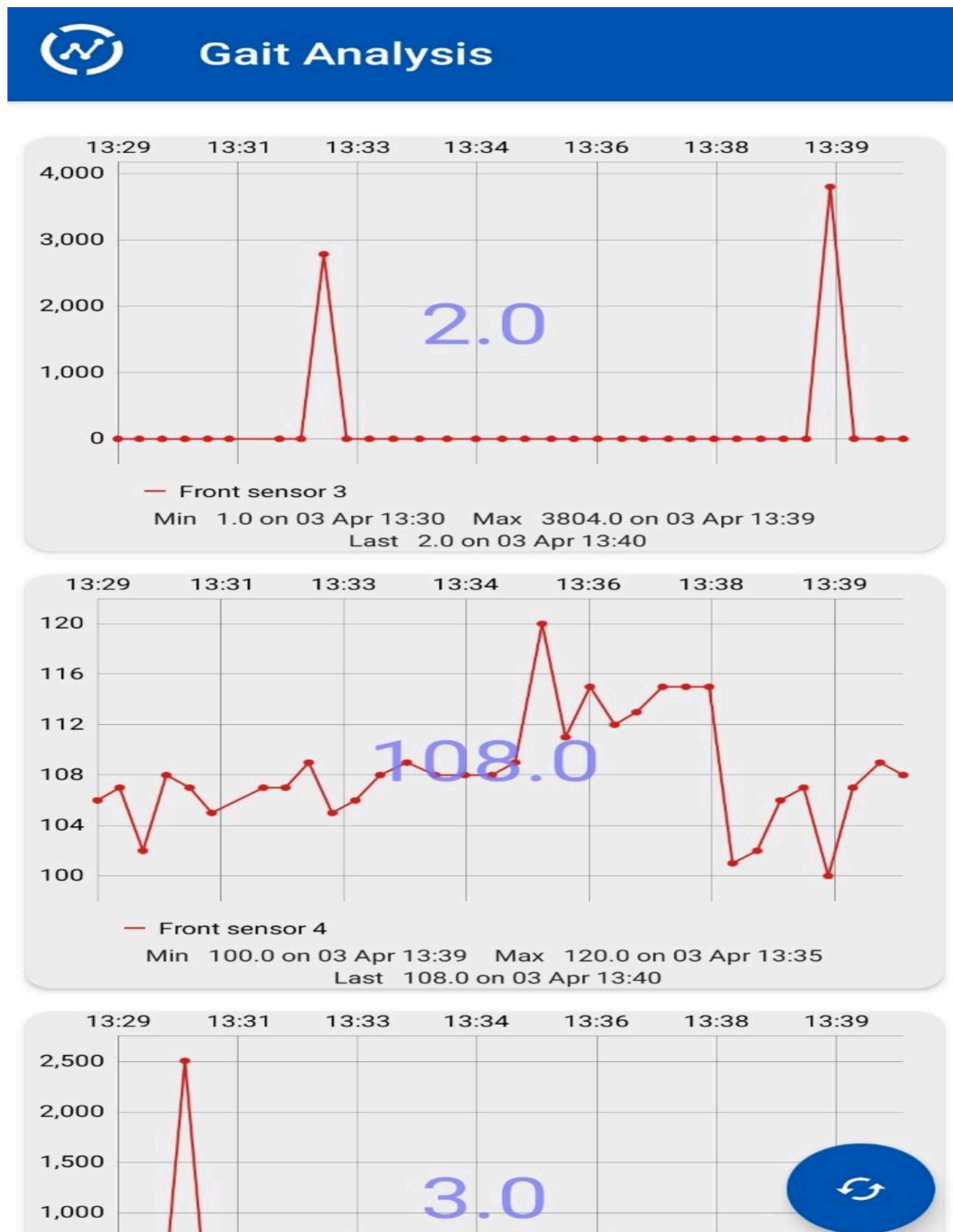


Fig: 5.7: Mobile application data of front sensor 3 and 4

Fig :5.7 shows the pressure value of 3rd and 4th sensors which is placed in the front side obtained in the mobile application.

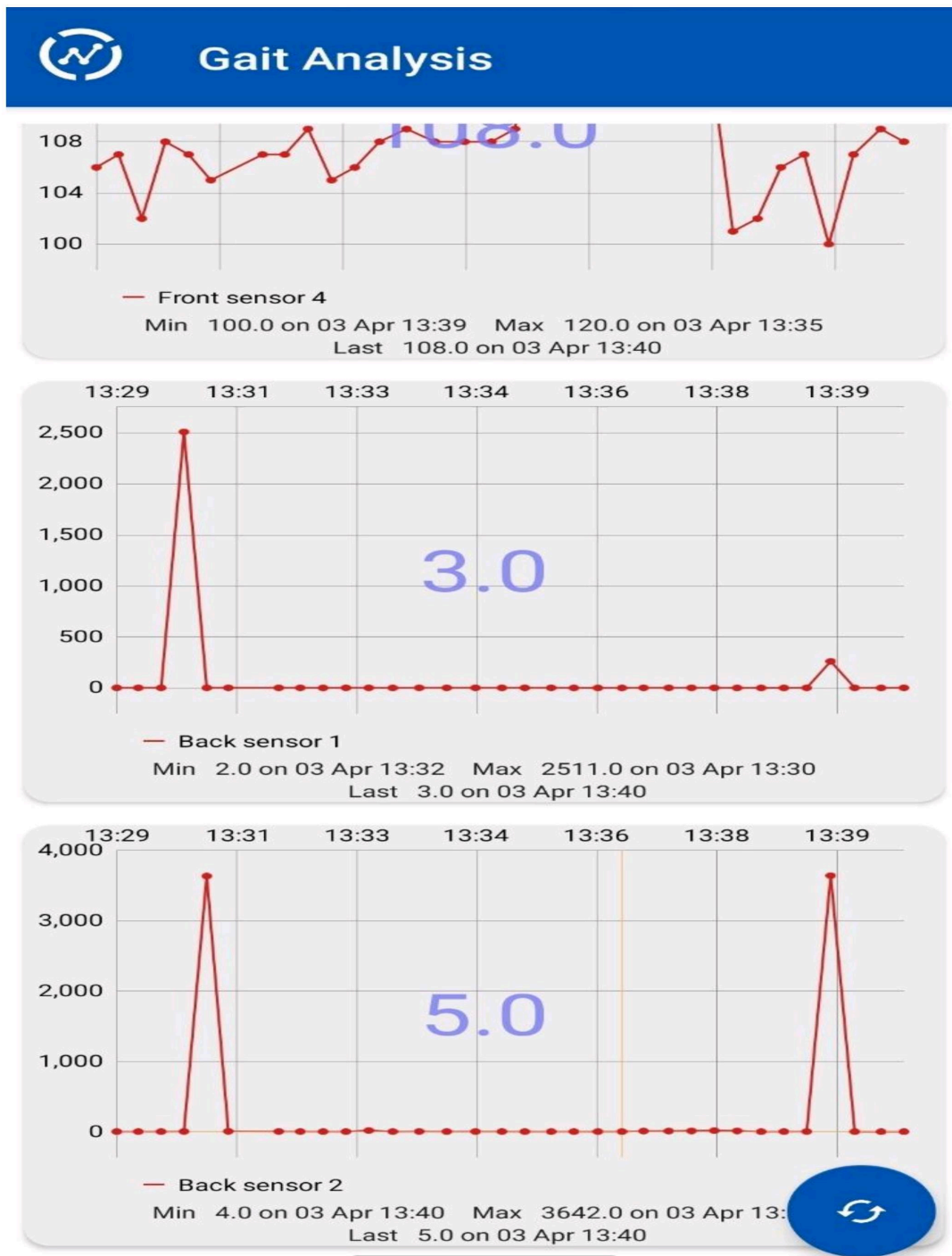


Fig: 5.8: Mobile application data of back sensors

Fig: 5.8 represents the graphical data obtained in the mobile application of the two back sensors

5.2.1.3. Excel Sheet Format

The data can be exported by the doctors in excel sheet format for the analysis of the patient. It shows the no. of entries which represents the no. of times the pressure value detected in the force sensor. Value of the pressure obtained in all 6 sensors and it also shows the date and time at which the pressure is recorded.

Table 5.1: Excel sheet of data analysis

A	B	C	D	E	F	G	H
created at	entries	field1	field2	field3	field4	field5	field6
2023-04-03T13:29:44+05:30	1	2706	81	2	106	3	6
2023-04-03T13:30:02+05:30	2	2772	61	2	107	3	6
2023-04-03T13:30:21+05:30	3	2610	56	1	102	3	6
2023-04-03T13:30:40+05:30	4	2752	59	1	108	2511	8
2023-04-03T13:30:59+05:30	5	2684	55	2	107	3	3635
2023-04-03T13:31:17+05:30	6	2668	51	2	105	3	10
2023-04-03T13:31:59+05:30	7	127	0	2	107	3	8
2023-04-03T13:32:17+05:30	8	110	0	2	107	3	7
2023-04-03T13:32:36+05:30	9	101	0	2787	109	2	6
2023-04-03T13:32:55+05:30	10	100	0	2	105	3	6
2023-04-03T13:33:14+05:30	11	108	6	2	106	3	21
2023-04-03T13:33:34+05:30	12	3222	128	2	108	2	6
2023-04-03T13:33:56+05:30	13	3256	140	2	109	3	8
2023-04-03T13:34:19+05:30	14	3771	91	2	108	3	7
2023-04-03T13:34:43+05:30	15	3802	94	2	108	3	7
2023-04-03T13:35:05+05:30	16	3404	79	2	108	3	7
2023-04-03T13:35:24+05:30	17	3160	69	2	109	3	6
2023-04-03T13:35:46+05:30	18	3110	74	2	120	3	6
2023-04-03T13:36:05+05:30	19	2150	35	2	111	2	6
2023-04-03T13:36:25+05:30	20	2979	59	2	115	2	6
2023-04-03T13:36:45+05:30	21	3873	3530	4	112	2	6
2023-04-03T13:37:03+05:30	22	219	0	2	113	3	13
2023-04-03T13:37:24+05:30	23	2684	60	2	115	3	13
2023-04-03T13:37:43+05:30	24	2444	41	2	115	3	16
2023-04-03T13:38:02+05:30	25	1912	24	2	115	3	19
2023-04-03T13:38:21+05:30	26	2508	40	2	101	2	16
2023-04-03T13:38:41+05:30	27	2510	40	2	102	2	5
2023-04-03T13:39:00+05:30	28	2732	46	2	106	2	6

2023-04-03T13:39:19+05:30	29	2457	39	2	107	3	7
2023-04-03T13:39:39+05:30	30	3903	156	3804	100	263	3642
2023-04-03T13:39:59+05:30	31	3224	3686	4	107	3	5
2023-04-03T13:40:21+05:30	32	2269	45	2	109	2	4
2023-04-03T13:40:40+05:30	33	2409	44	2	108	3	5
2023-04-03T13:40:58+05:30	34	2419	33	2	107	3	6
2023-04-03T13:41:16+05:30	35	2423	34	2	110	3	6
2023-04-03T13:41:38+05:30	36	2459	1079	1185	102	2663	2082
2023-04-03T13:41:56+05:30	37	2458	38	285	110	3	6
2023-04-03T13:42:14+05:30	38	2389	34	2	110	3	6
2023-04-03T13:42:32+05:30	39	2601	40	2	105	2	6
2023-04-03T13:42:50+05:30	40	2564	40	1	110	3	11
2023-04-03T13:43:09+05:30	41	2555	38	2	110	3	6
2023-04-03T13:43:27+05:30	42	2563	39	2	109	3	6
2023-04-03T13:43:46+05:30	43	2381	34	2	113	3	6
2023-04-03T13:44:06+05:30	44	2475	38	2	104	2838	3306
2023-04-03T13:44:27+05:30	45	4056	84	2520	3090	2	3575
2023-04-03T13:44:49+05:30	46	1898	1881	3	111	3	219
2023-04-03T13:45:11+05:30	47	2427	3284	1128	2671	3	2210
2023-04-03T13:45:31+05:30	48	2124	37	2	113	3	6
2023-04-03T13:45:50+05:30	49	2257	40	2	113	35	6
2023-04-03T13:46:09+05:30	50	2244	38	2	114	2	5
2023-04-03T13:46:27+05:30	51	2337	41	2	114	42	5
2023-04-03T13:46:46+05:30	52	2157	32	2	114	41	5
2023-04-03T13:47:04+05:30	53	2186	32	2	114	43	5
2023-04-03T13:47:23+05:30	54	2484	40	1	114	44	5
2023-04-03T13:47:42+05:30	55	2751	47	2	114	44	5
2023-04-03T13:48:01+05:30	56	2279	30	1	114	47	6
2023-04-03T13:48:19+05:30	57	2397	33	2	114	47	5
2023-04-03T13:48:38+05:30	58	2400	35	2947	112	3	3029
2023-04-03T13:48:58+05:30	59	2174	29	2	113	3	5
2023-04-03T13:49:18+05:30	60	2842	45	2109	2034	2520	2550
2023-04-03T13:49:40+05:30	61	2057	28	2	112	3	4

Table 5.1 represents the excel sheet data where it has the description the columns as follows

A – date and time of the pressure recorded

B – No. of entries

C, D, E, F, G, H – Pressure values of 4 front sensors and 2 back sensors respectively.

5.2.2. LCD Display Data

The data of the pressure analysis can be viewed in offline mode by the LCD display connected with the circuit. It shows the average value of the pressure given in the force sensors (i.e.) the values of 4 front sensors and 2 back sensors are averaged.



Fig: 5.9: LCD display data

Fig: 5.9 shows the pressure value in the LCD display. It is the averaged value of the pressure values, where F represents the averaged value of front sensor and B represents the averaged value of back sensor.

5.3. PERFORMANCE AND APPLICATION

5.3.1. Performance

Gait analysis is the study of human locomotion, and it can be used to detect abnormalities or changes in the way people walk. Force sensors can be used to measure the forces exerted on the ground during each step, which can provide valuable information for gait analysis. The ESP32 microcontroller is a powerful and low-cost device that can be used to collect and process data from force sensors.

5.3.2. Application

- Useful for elderly people.
- People with Gait disorders.
- Neurological disorders like Parkinson's disease, stroke which will affect the gait cycle.
- Early diagnosis of gait disorder.
- Useful for accident victims.

CHAPTER – 6

SUMMARY AND CONCLUSION

The gait analysis project using an ESP32 microcontroller and force sensors aims to design and develop a low-cost and effective system for studying human locomotion and identifying abnormalities or changes in gait. The project involves selecting appropriate hardware components, developing software to collect and process data from force sensors, calibrating the system using known weights, collecting data from people walking, and analysing the data using software such as MATLAB or Python. The results will be interpreted in the context of the problem being addressed, considering the limitations of the system and potential sources of error. The project has the potential to contribute to the development of low-cost and effective gait analysis systems, which can be used to improve the diagnosis and treatment of gait-related conditions. The system can provide valuable information for researchers, clinicians, and physical therapists who are interested in studying human locomotion and identifying abnormalities or changes in gait.

In future works, the microcontroller and other components can be sandwiched in the insole of the shoe and can be concealed inside the shoe, where the power supply can be generated by the pressure applied. Further this technology can also be applied in any type of footwear for day-to-day use.

REFERENCES

- [1].Ailneni. R .C, Syamala.K. R, Kartheek, I.-Kim S, and Hwang. J, “Influence of the wearable posture correction sensor on head and neck posture: Sitting and standing workstations,” *Work*, vol. 62, 2019, pp. 27–35.
- [2].Balthillaya GM, Parsekar SS, Gangavelli R, et al Effectiveness of posture-correction interventions for mechanical neck pain and posture among people with forward head posture: protocol for a systematic review *BMJ Open* 2022; pp 1972 – 1975.
- [3].Gaikwad. N. B, Tiwari. V, Keskar. A, and Shivaprakash. N, “Efficient fpga implementation of multilayer perceptron for real-time human activity classification,” *IEEE Access*, vol. 7, 2019, pp. 26 696–26 706.
- [4].Hari Prasanth, Miroslav Caban ,Urs Keller , Grégoire Courtine, Auke Ijspeert , Heike Vallery and Joachim von Zitzewitz . Wearable Sensor-Based Real-Time Gait Detection: A Systematic Review; Jochen Klenk *Sensors* 2021, 21(8), pp.2727-2735.
- [5].Hegde, N., Zhang, T., Uswatte, G., Taub, E., Barman, J., McKay, S., ... Sazonov, E. S. The Pediatric SmartShoe: Wearable Sensor System for Ambulatory Monitoring of Physical Activity and Gait. *IEEE Transactions on Neural Systems and Rehabilitation Engineering*, 26(2), 2018, pp 477–486.
- [6].Hubble RP, Naughton GA, Silburn PA, Cole MH Wearable Sensor Use for Assessing Standing Balance and Walking Stability in People with Parkinson’s Disease: A Systematic Review. *PLoS ONE*, 2015, 10(4), pp 79-85.
- [7].Ishaku, “Flexible force sensors embedded in office chair for monitoring of sitting postures,” in *Proceedings of the IEEE International Conference on Flexible and Printable Sensors and Systems (FLEPS)*, Glasgow, UK, 2019, pp. 1–9.
- [8].Jacek Lorkowski, Karolina Gawronska, Mieczyslaw Pokorski. Pedobarography: A Review on Methods and Practical Use in Foot Disorders; November 2021 *Applied Sciences* 11(22): pp 11020-11029.
- [9].JefersonSilva da Rocha, RobertoPoton, Lorena Rosa, Nádia Lima da Silva, PauloFarinatti. Pilates and improvement of balance and posture in older adults: A

- meta-analysis with focus on potential moderators; Health Sciences Review Volume 5, December 2022, pp 1054-1065.
- [10]. Jonathan Kofman, Julie Nantel and Edward D. Lemaire. Wearable-Sensor-Based Detection and Prediction of Freezing of Gait in Parkinson's Disease; Sensors 2019, 19(23), pp 5141-5149
 - [11]. Karolina Gawronska and Jacek Lorkowski . Evaluating the Symmetry in Plantar Pressure Distribution under the Toes during Standing in a Postural Pedobarographic Examination: August 2021, 5(12), pp 111-115.
 - [12]. Lee, R.; James, C.; Edwards, S.; Skinner, G.; Young, J.L.; Snodgrass, S.J. Evidence for the Effectiveness of Feedback from Wearable Inertial Sensors during Work-Related Activities: A Scoping Review. Sensors 2021, vol.21, pp 6377-6379.
 - [13]. Masataka Yamamoto, Koji Shimatani, Yuto Ishige¹ & Hiroshi Takemura "Verification of gait analysis method fusing camera-based pose estimation and an IMU sensor in various gait conditions Published on December 2022, pp-1022-1030.
 - [14]. Monica Chhabra, Sharad Prabhakar, Devendra K Chouhan, Mandeep S Dhillon "Technical Note: Three-dimensional Gait Analysis", Journal of Postgraduate Medicine, Education and Research (2021): 10.5005/jp-journals- pp 10028-1445.
 - [15]. Mukhopadhyay. S. C, "Wearable Sensors for Human Activity Monitoring: A Review," in IEEE Sensors Journal, vol. 15, no. 3, March 2018, doi: 10.1109/JSEN.2014.2370945, pp. 1321-1330.
 - [16]. Nagaraj Hegde, Matthew Bries and Edward Sazonov Enzo Pasquale Scilingo and Gaetano Valenza. A Comparative Review of Footwear-Based Wearable Systems; Received: 14 July 2016; Published: 10 August 2016, pp 786-794.
 - [17]. Nagaraj Hegde; Ting Zhang; Gitendra Uswatte; Edward Taub; Joydip Barman; Staci McKay. The Pediatric SmartShoe: Wearable Sensor System for Ambulatory Monitoring of Physical Activity and Gait; IEEE Transactions on Neural Systems and Rehabilitation Engineering, Volume: 26, Issue: 2, February 2018, pp 143-148.

- [18]. Nitin Khadane, Gait Motion Analysis using Arduino and Blender 3d Software International Journal of Engineering Research & Technology (IJERT) <http://www.ijert.org> ISSN: 2278-0181 IJERTV8IS120363 (Vol. 8 Issue 12, December-2019, pp 286-290.
- [19]. Qi song Hu, Student Member, IEEE, Xiaochen Tang, Student Member, IEEE, and Wei Tang, Member, IEEE; A Smart Chair Sitting Posture Recognition System Using Flex Sensors and FPGA Implemented Artificial Neural Network; IEEE Sensors Journal, VOL. XX, NO. XX, XXXX 2020, pp 1979-1984.
- [20]. Rajesh P, Pranav Anand P, Rupesh Babu C, Varshini Karthik and Ashok Kumar Affordable human motion analysis system 3rd International Conference on Advances in Mechanical Engineering (ICAME 2020), pp 2002- 2009.
- [21]. Rinki Gupta, Sindhu Hak Gupta, Anshdeep Agarwal, Priya Choudhary, Nikita Bansal, Smita Sen. A Wearable Multi-Sensor Posture Detection System Proceedings of the International Conference on Intelligent Computing and Control Systems; (ICICCS 2020) IEEE Xplore Part Number: CFP20K74-ART; ISBN: 978-1-7281-4876-2, pp 2005-2010.
- [22]. Shanshan Chen, John Lach, Benny Lo, and Guang-Zhong Yang, "Toward Pervasive Gait Analysis with Wearable Sensors: A Systematic Review" IEEE Journal of Biomedical and Health Informatics, vol. 20, no. 6, November 2017, pp 591-595.
- [23]. Shahzad Muzaffar, Ibrahim (Abe) M Elfadel Khalifa University. Shoe-Integrated, Force Sensor Design for Continuous Body Weight Monitoring June 2020 Sensors 20(12):3339 DOI:10.3390/s20123339, pp 195-198.
- [24]. Slavomir Matuska, Martin Paralic, and Robert Hudec. A Smart System for Sitting Posture Detection Based on Force Sensors and Mobile Application; Hindawi Mobile Information Systems Volume 2020, Article ID 6625797, 13 pages (2020).
- [25]. Tang .X, Hu. Q, and Tang. W, "A real-time qrs detection system with pr/rt interval and st segment measurements for wearable ecg sensors using parallel delta modulators," IEEE transactions on biomedical circuits and systems 2018, vol. 12, no. 4, pp. 751–761.

- [26]. WangYan, CangShuang, YuHongnian. A survey on wearable sensor modality centred human activity recognition in health care; Expert Systems with Applications Volume 137, 15 December 2019, pp 958-960.
- [27]. YantaoYu, WaleedUmer, XincongYang, Maxwell Fordjour, Antwi-Afari. Posture-related data collection methods for construction workers Automation in Construction Volume 124, April 2021, 103538 - 103540

APPENDIX

```
#include <MCP3208.h>
#include <SPI.h>
#include <Wire.h>
#include <LiquidCrystal_PCF8574.h>
#include <Wire.h>

// projectMT2023

#include <ESP8266WiFi.h>
#include "ThingSpeak.h"

char ssid1[] = "Project";
char password1[] = "1234567890";

unsigned long channelID = 2079596;
const char* writeAPIKey = "652AT34KWUGE36MM"; // write API key for your
ThingSpeak Channel
const char* server = "api.thingspeak.com";

int tup = 20;

WiFiClient client;

// LiquidCrystal lcd(13, 12, 11, 10, 9, 8);
// LiquidCrystal lcd(8,9,10,11,12,13);
LiquidCrystal_PCF8574 lcd(0x27);
```

```
#define splash splash1
```

```
#define fsr0 0
```

```
#define fsr1 1
```

```
#define fsr2 2
```

```
#define fsr3 3
```

```
#define fsr4 4
```

```
#define fsr5 5
```

```
int fsr0_r = 0;
```

```
int fsr1_r = 0;
```

```
int fsr2_r = 0;
```

```
int fsr3_r = 0;
```

```
int fsr4_r = 0;
```

```
int fsr5_r = 0;
```

```
MCP3208 adc(D8);
```

```
#define vb1 D3
```

```
#define vb2 D4
```

```
void setup() {
```

```
    // put your setup code here, to run once:
```

```
    Serial.begin(115200);
```



```

pinMode(vb1, OUTPUT);
pinMode(vb2, OUTPUT);
digitalWrite(vb1, LOW);
digitalWrite(vb2, LOW);
LcDSet();
setupWifi();
adc.begin();
ThingSpeak.begin(client);
}

```

```

void setupWifi() {

    Serial.println();
    Serial.println();
    Serial.print(ssid1);
    WiFi.begin(ssid1, password1);
    Serial.print("Connecting to ");
    delay(2000);
    if (WiFi.status() != WL_CONNECTED) {
        delay(800);
        Serial.print(".");
        Serial.println("");
        Serial.println("WiFi connected");
        Serial.println("IP address: ");
        Serial.println(WiFi.localIP());
        delay(1000);
    }
}

```

```

void LcDSet() {

```

```

    lcd.begin(16, 2);
    // Print a message to the LCD.
    lcd.clear();
    lcd.setBacklight(1);
    splash(0, "GAIT");
    splash(1, "Monitoring");

    delay(2000);
    lcd.clear();
}

void loop() {
    // put your main code here, to run repeatedly:
    getSensors();
    UpdateServer();
    int b1_avg = (fsr0_r + fsr1_r) / 2;
    int f_avg = (fsr2_r + fsr3_r + fsr4_r + fsr5_r) / 4;

    lcd.setCursor(0, 0);
    lcd.print("F :      ");
    lcd.setCursor(3, 0);

    lcd.print(f_avg);

    lcd.setCursor(8, 0);
    lcd.print("B :      ");
    lcd.setCursor(11, 0);

    lcd.print(b1_avg);

```

```
if (f_avg > 1800) {  
    digitalWrite(vb1, HIGH);  
    delay(100);  
    digitalWrite(vb1, LOW);  
}
```

```
if (b1_avg > 1800) {  
    digitalWrite(vb2, HIGH);  
    delay(100);  
    digitalWrite(vb2, LOW);  
}
```

```
delay(300);  
}
```

```
void getSensors() {  
    fsr0_r = adc.analogRead(fsr0);  
    fsr1_r = adc.analogRead(fsr1);  
    fsr2_r = adc.analogRead(fsr2);  
    fsr3_r = adc.analogRead(fsr3);  
    fsr4_r = adc.analogRead(fsr4);  
    fsr5_r = adc.analogRead(fsr5);
```

```
    Serial.print(fsr0_r);  
    Serial.print(",\t");  
    Serial.print(fsr1_r);  
    Serial.print(",\t");
```

```

Serial.print(fsr2_r);
Serial.print(",\t");
Serial.print(fsr3_r);
Serial.print(",\t");
Serial.print(fsr4_r);
Serial.print(",\t");
Serial.print(fsr5_r);
Serial.print(",\t");
Serial.println();
}

```

```

void UpdateServer() {

```

```

    tup++;

```

```

    if (tup >= 50) {

```

```

        if (client.connect(server, 80)) {

```

```

            ThingSpeak.setField(1, String(fsr0_r));

```

```

            ThingSpeak.setField(2, String(fsr1_r));

```

```

            ThingSpeak.setField(3, String(fsr2_r));

```

```

            ThingSpeak.setField(4, String(fsr3_r));

```

```

            ThingSpeak.setField(5, String(fsr4_r));

```

```

            ThingSpeak.setField(6, String(fsr5_r));

```

```

            // write to the ThingSpeak channel

```

```

            int x = ThingSpeak.writeFields(channelID, writeAPIKey);

```

```

            if (x == 200) {

```

```

                Serial.println("Channel update successful.");

```

```

            } else {

```

```
        Serial.println("Problem updating channel. HTTP error code " + String(x));  
    }  
}  
tup = 0;  
}  
}
```