ELE402 GRADUATION PROJECT-II

FINAL REPORT

HACETTEPE UNIVERSITY
DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

Project Title: Wearable Sensor-Based System for Detecting Neck and Back Posture Problems

Name: Ömer Kenan Uçmaklıoğlu
Student ID: 21628846

Name: Recep Tolunay Lezgi
Student ID: 21828695

Project Supervisor: Asst.Prof.Dr. Şölen Kumbay Yıldız
Project Co-supervisor: Prof.Dr. Atila Yılmaz

Submission Date: 03.10.2023

SUMMER 2022-2023

Abstract

Our senior project is that "Wearable Sensor-Based System for Detecting Neck and Back Posture Problems". Wearable devices can provide real-time feedback regarding a person's health conditions; hence, they can provide an objective alternative to manage and monitor chronic disease progression, such as with the elderly, within rehabilitation, and for those with various disabilities. Wearable sensor should be used more than medical devices which are have the same function due to their lower cost , hardware capabilities and small footprint. A wearable solution has three major components: Hardware, communication gateways, software. In this project , we use flex sensors which are Resistive Flex Sensors (RFSs) their working prenciple is the electrical resistance variation of a conductive material with the bending, accelerometers and gyroscopes. They work together to provide information about the object's movement and orientation in three-dimensional space. With this information we can disease diagnosis and monitoring and improve sensors' sensitivity and instantaneity performance. In this project , our task is process real-time information of sensors and the most appropriate way is to place a wearable sensor on the clothing with the results we obtained from our studies.

Table of Contents

List of Figures

1 Introduction

Our senior project is that “Wearable Sensor-Based System for Detecting Neck and Back Posture Problems”. Wearable devices can provide real-time feedback regarding a person’s health conditions; hence, they can provide an objective alternative to manage and monitor chronic disease progression, such as with the elderly, within rehabilitation, and for those with various disabilities.

Wearable sensor should be used more than medical devices which are have the same function due to their lower cost , hardware capabilities and small footprint. A wearable solution has three major components: Hardware, communication gateways, software. In this project , we use flex sensors which are Resistive Flex Sensors (RFSs) their working prenciple is the electrical resistance variation of a conductive material with the bending, accelerometers and gyroscopes. They work together to provide information about the object’s movement and orientation in three-dimensional space. With this information we can disease diagnosis and monitoring and improve sensors’ sensitivity and instantaneity performance.

In this project , our task is process real-time information of sensors and the most appropriate way is to place a wearable sensor on the clothing with the results we obtained from our studies.

2 Project Description

This project is an electrical and electronics engineering graduation project. The topic of this project is creating wearable sensor-based system for detecting neck and back posture problems. In this project, available sensors on the industry should be investigated and should be picked ones that project needed.

The work of this project is choosing the sensor that about to work and determining its properties with experiments to know exact behaviour on different situations. Using that knowledge, designing a proper system according to needs.

According to research that team members made, group chose to work with flex sensors. The reason of choosing flex sensor is increasingly used in different areas for their interesting property to change their resistance when bent. In particular, they can be applied to human segment in biomedical devices to register static and dynamic postures. In spite of their interesting properties, such as robustness, low price and long life, they often demonstrate non-linear response and lower sensitivity at small bending angles [1].

The research team employed gyrosensors as supplementary data channels to validate and corroborate certain parameters derived from flex sensors.

3 Engineering Standards and Design Constraints

This theoretical research and practical design project is an engineering graduation project. Also this project related with human body and health, there are important standards to provide human safety. This standards and constraints provide robust and reliable projects.

3.1 Engineering Standards

IEC 62304:2006 Defines the life cycle requirements for medical device software. The set of processes, activities, and tasks described in this standard establishes a common framework for medical device software life cycle processes.

IEEE 360-2022 Wearable Consumer Electronic Devices (Wearables) are given an overview, terminology, and categorization in this standard. An architecture for a series of standard specifications that define technical requirements and testing methods for different aspects of wearables–from basic security and suitableness of wear to various functional areas, such as health, fitness, and infotainment–is further outlined.

3.2 Design Constraints

• Designs that can be physically implemented. • Designs that do not violate safety and health issues. • Designs that suit to current manufacturing technology. • Safety of the consumers of the product.

4 Sustainable Development Goals

Sustainable Development Goals (SDGs) is (also known as Global Goals) a universal call made by the United Nations in 2015. They are 17 goals; no poverty, quality education, gender equality, clean energy etc. These goals aim to stop the poverty, protect the planet, global peace and prosperity by 2030.

This project is directly related to these goals. Goal 3 (Ensure healthy lives and promote well-being for all at all ages) is the most related goal with this project. This project want to solve neck and back posture problems using wearable sensor based system. This could make human body better for all ages.

5 Background

This project has a lot of work in the background because this project has theoretical work with practical design. Most of the backgrounds are in the undergraduate program of Electrical and Electronics Engineering.

5.1 Background Acquired In Earlier Course Work

Firstly, in freshman year mathematics and physics classes, are important which is MAT123, MAT124, FIZ137 and FIZ140 because they are the first step of background. In these classes, students learn dimensional derivatives and integrals and their applications in experiment setups. Secondly in sophomore year, the electrical and electronics engineering program has engineering circuit theory classes. They are ELE203 and ELE220. These classes teach defining circuit elements and designing needed circuits. These classes are very important because in this project team should analyze circuit elements and design the circuit needed. Then, in the junior year, the program has Signals and Systems class (ELE301). It is an important class because it includes Fourier Transform, Laplace Transform and their discrete-time analogous. These topics teach understanding and analyzing systems. Finally, this project needs a software background. Computers and Programming-1 (ELE107), Computers and Programming-2 (ELE118) and Microprocessor Architecture and Programming (ELE336) classes teach understanding the digital world, understanding-designing an algorithm and develop a program.

5.2 Background Acquired Through Additional Research

This project has some additional research. The first part of this project is theoretical. This theoretical part includes having knowledge about biomedical engineering to design systems. Project members should be familiar with biomedical terms to understand language of the area they are working. Researching available papers according to area and having knowledge about the theory is important point to compare experiment results with theory.

6 Methods

In the scope of this project, the primary objective was the development of a real-time data acquisition system for subjects. To achieve this, it was imperative to establish a responsive framework. After conducting extensive research, the choice was made to employ STM32 microcontroller boards due to their commendable proficiency in data acquisition from both analog and digital sensors. These boards were particularly well-suited for executing the algorithmic computations necessary for angle determination using flex sensors. Moreover, their versatile range of communication modules facilitated seamless data transmission to external systems, optimizing the efficiency of data retrieval.

Another critical facet of the design framework was the imperative of simplicity. Ensuring a streamlined and comprehensible system architecture was deemed essential to facilitate rapid comprehension and development by new team members as required.

6.1 Method 1

One feasible approach for constructing the system entails implementing a wired communication infrastructure. This method is characterized by its fundamental simplicity and efficiency in data transfer rates, facilitating rapid and real-time data acquisition. However, it is important to acknowledge a significant drawback associated with this design paradigm. Specifically, the tethering of subjects to the system via wired connections imposes limitations on their freedom of movement, potentially impeding their ability to perform essential motions. These movement constraints are particularly problematic in scenarios requiring specific, unrestricted maneuvers. Furthermore, there are potential instances where subjects may find it impractical or uncomfortable to don the orthosis under certain conditions. Consequently, after careful consideration, an alternative approach was selected, which had not been previously explored.

6.2 Method 2

In pursuit of enhancing subject comfort within the system, a strategic decision was made to transition towards a wireless communication framework, leveraging Wi-Fi technology. The adoption of Wi-Fi technology offered several distinct advantages, notably the capacity to concurrently transmit raw data to multiple servers while simultaneously acquiring real-time data from multiple subjects. This approach conferred three salient benefits to the system's architecture:

1. Enhanced Subject Comfort: By eliminating the necessity for wired connections, the wireless configuration mitigated restrictions on subject mobility and, thereby, improved overall comfort during data acquisition.

2. Versatile Server Integration: The utilization of Wi-Fi technology afforded the flexibility to feed data to a diverse array of servers, thereby diversifying the data processing and storage capabilities of the system.

3. Concurrent Data Collection from Multiple Subjects: The wireless approach enabled the concurrent collection of data from multiple subjects in real time, facilitating the study of simultaneous subject interactions and behaviors.

Subsequently, after careful deliberation, this method was selected as the optimal solution for the system.

7 Preliminary Design

In the design phase, the inclusion of an STM32 microcontroller and requisite sensors was deemed essential. It is worth noting that while certain STM32 boards are equipped with integrated Wi-Fi modules, our specific hardware did not possess this capability. Consequently, an in-depth investigation was conducted, culminating in the selection of a Wi-Fi module known as NodeMCU. Notably, NodeMCU is characterized by its integral Wi-Fi board, rendering it a favorable choice for our project.

One pivotal advantage of NodeMCU was its compatibility with the Arduino interface, enabling the programming of NodeMCU units. This capability played a pivotal role in the segregation of the project into two distinct domains: the web interface component and the embedded component. This segregation is of particular significance, as it empowers individuals, including web designers without specialized embedded knowledge, to engage in the coding process. Consequently, this architecture facilitates streamlined User Interface (UI) adjustments and enhancements, as they can be executed with greater ease.

Communication between the STM32 microcontroller and the NodeMCU module was established through UART (Universal Asynchronous Receiver-Transmitter) modules. The STM32 microcontroller actively retrieves data from the gyrosensors and flex sensors, performs requisite calculations, and subsequently transmits this processed data to the NodeMCU module. NodeMCU, in turn, serves as a conduit for rendering this data accessible via a local web page. Furthermore, NodeMCU possesses the capability to transmit raw data in response to client requests, thereby enabling seamless integration with downstream implementations.

8 Prototype

In the laboratory setting, physical connections were established, and a set of sample data points were generated using the STM32 microcontroller. These generated data points were subsequently transmitted to the NodeMCU module. Subsequently, a rudimentary web page was crafted to visualize and present these data points. The prototype's functionality was rigorously tested and found to operate seamlessly, demonstrating the successful implementation of the initial proof of concept.

9 Design Process

9.1 Iteration 1

The initial phase of the project involved the acquisition of analog data from flex sensors, necessitating the development of a circuit design tailored to the unique behavior of these sensors. Flex sensors, which exhibit characteristics akin to variable resistors, undergo changes in their resistance values when subjected to bending or deformation.

Subsequently, we devised a circuit design that essentially functioned as a voltage divider. This circuit leveraged the variability in resistance exhibited by the flex sensor to modulate the output voltage, thereby enabling the detection of changes in the sensor's behavior. This voltage variation, in turn, provided the foundation for deriving meaningful data. However, a pivotal prerequisite in this process was the determination of the default resistance of the flex sensor.

To ascertain this fundamental parameter, we devised a calibration methodology. When the flex sensor was positioned in a flat or neutral state, users were prompted to initiate the calibration process. This procedure spanned a duration of approximately three seconds, during which the system computed and established the baseline resistance value for the flat sensor configuration. The attainment of this baseline was instrumental in enabling subsequent algorithmic operations, ensuring the precise calculation of data from the flex sensor readings.

In our data acquisition process, we interfaced with a gyrometer to retrieve data through the I2C communication protocol. This involved establishing a

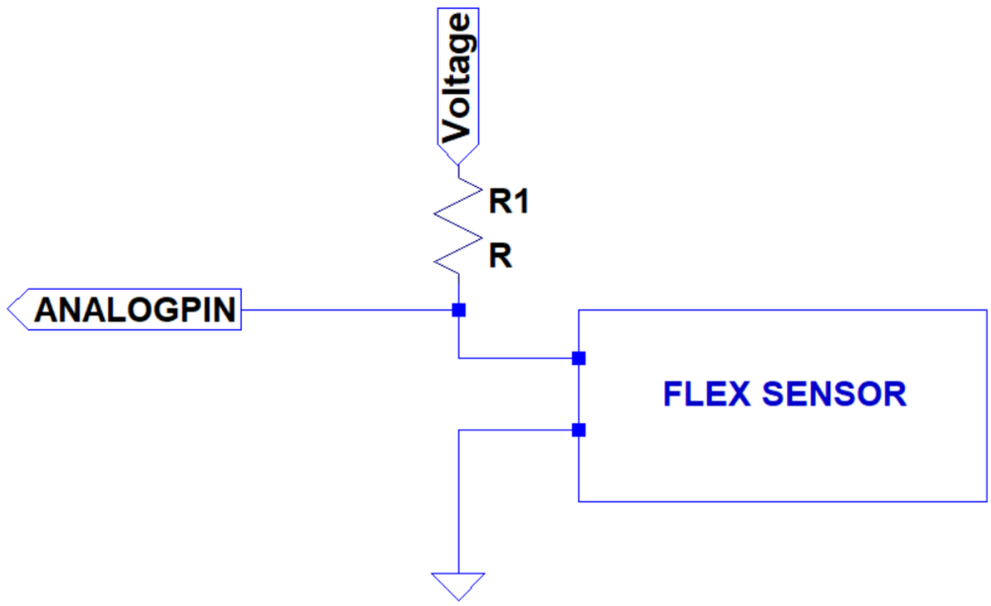

Figure 1: Analog Circuit Design

connection to the gyrometer's I2C interface, allowing us to effectively capture relevant data from the sensor.

The amassed dataset, comprising both flex sensor readings and gyrometer data, was then transmitted to the NodeMCU module via the UART (Universal Asynchronous Receiver-Transmitter) communication module. This bi-directional serial communication facilitated the efficient and synchronized transfer of the collected data from the STM32 microcontroller to the NodeMCU module, where further processing and dissemination were executed.

9.2 Iteration 2

Our research team established a data communication protocol utilizing UART to retrieve information transmitted from the STM32 microcontroller. Subsequently, we embarked on the development of a web-based User Interface (UI) as an integral component of our system. Notably, this UI was enriched with animations, strategically designed to visualize angle bendings in real-time. This visual representation served to enhance the interpretability of system outputs, facilitating comprehension and analysis by scientific stakeholders.

The web-based UI was constructed using a combination of HTML, CSS, and JavaScript technologies, leveraging their collective capabilities to create an interactive and informative platform.

To enhance system versatility and utility, we incorporated a calibration functionality accessible through a designated button within the UI. Upon user input, NodeMCU facilitated the transmission of calibration parameters to the STM32 microcontroller. Subsequently, the STM32 executed the necessary calibration procedures, ensuring the system's accuracy and reliability.

Furthermore, recognizing the ubiquity of the JSON file format in the industry, we opted to utilize it for sharing raw data. To accommodate this choice, we implemented a JSON-based Application Programming Interface (API) within our local server. This API serves as an accessible conduit through which clients can dynamically retrieve real-time data, thereby extending the potential for further application development and integration, including the prospect of artificial intelligence (AI) systems.

10 Final Design

The integration process involved the establishment of a seamless connection between our data acquisition system and an existing orthosis, readily available within our laboratory. Subsequently, we formulated a straightforward yet effective design, which was then translated into a physical implementation on the selected orthosis. This implementation facilitated the collection of data through our designed system.

Through rigorous testing and experimentation, we were able to validate the functionality of our system, manifesting in real-time data updates within the web interface, the successful calibration of the STM32 microcontroller, and the accessibility of data via the previously developed API. Notably, the acquired dataset was processed using MATLAB, enabling us to empirically verify the robust performance of the API, thereby affirming its seamless and reliable operation.

10.1 Meeting The Constraints And Engineering Standards

Our system has been rigorously evaluated against established standards and constraints, aligning with the requirements of IEC 62304:2006 and IEEE 360-2022. This comprehensive assessment underscores the system's adherence to recognized engineering standards and its overall compliance with the specified constraints.

10.2 Test Results and Images

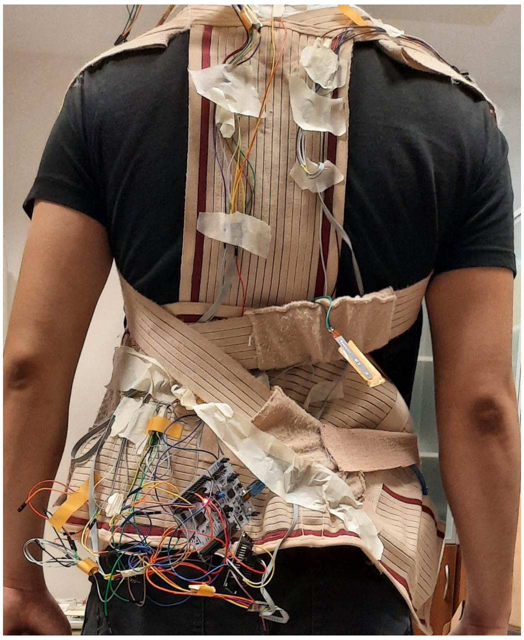

Figure 2: Final System View

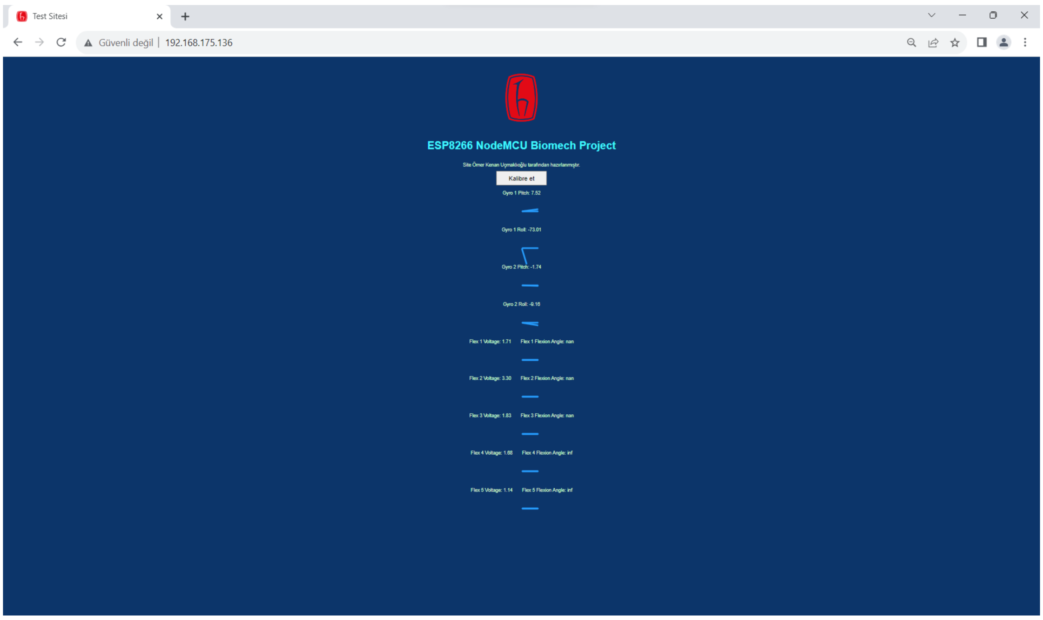

Figure 3: User Interface

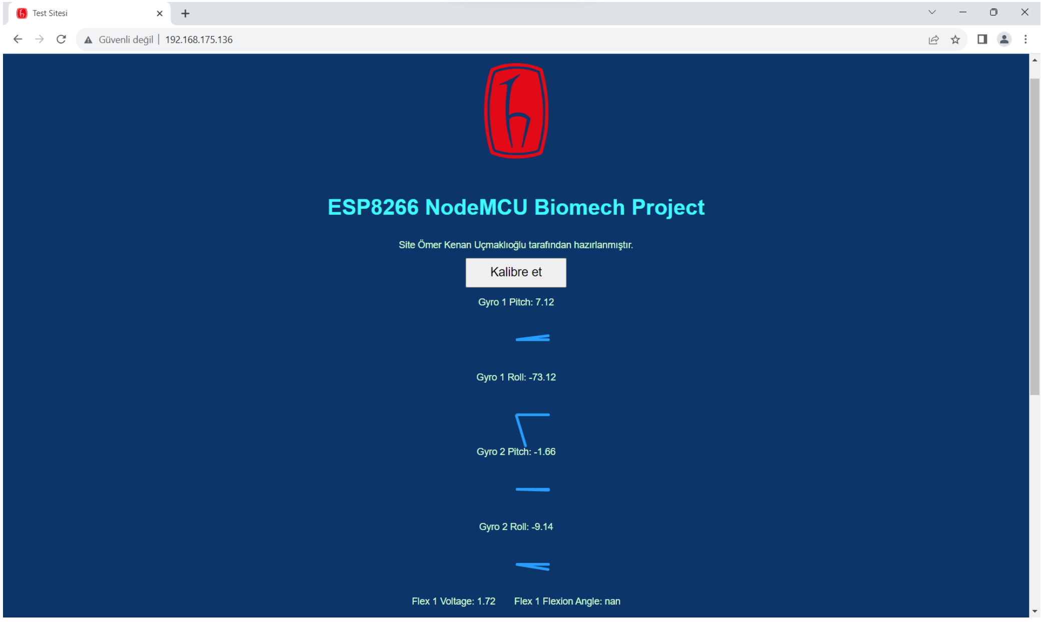

Figure 4: Calibration Button

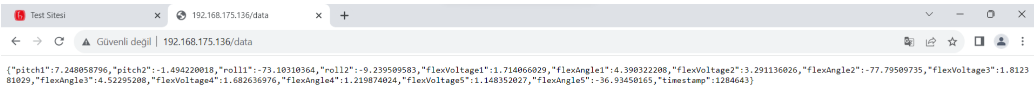

Figure 5: Raw Data with JSON

11 Team Work

Within our team, comprising two members, a collaborative approach was adopted throughout the entirety of the project. Each team member assumed specialized roles in distinct areas of expertise. Specifically, Tolunay undertook the calibration and configuration of the gyrometer parameters and managed the communication aspects related to raw data. Conversely, Ömer was primarily responsible for the development and customization of the User Interface, as well as the design and implementation of algorithms dedicated to angle detection. This division of labor allowed for a focused and efficient execution of tasks, leveraging the complementary skill sets of both team members.

12 Conclusion

During the preceding semester, our team conducted a comprehensive investigation into the behavior of flex sensors, culminating in the establishment of a characterization framework. Building upon this foundational understanding, we formulated a mathematical algorithm designed to predict angular variations through the utilization of flex sensors. Concurrently, the incorporation of gyrosensors played a pivotal role, validating the data acquired from flex sensors and contributing additional dimensions of information.

The culmination of these efforts yielded a sophisticated system for the acquisition and dissemination of crucial data, in real-time, with the potential for integration into subsequent systems. These real-time data collection capabilities hold promise for diverse applications, such as integration into artificial intelligence (AI) platforms or for the examination and analysis of complex problem behaviors. Importantly, this system holds the capacity to characterize a spectrum of medical conditions and illnesses through the acquisition of pertinent data.

References

[1] Giovanni Saggioa, Giancarlo Orengoa, "Flex sensor characterization against shape and curvature changes", Sensors and Actuators A: Physical, Volume 273, Pages 221-231, 2018.

[2] David A. Winter, "Biomechanics and Motor Control of Human Movement", USA/New Jersey, John Wiley Sons, 2005.

[3] Jones, Paul S., and Heikki Uustal. "Spinal Orthoses: Principles, Designs, Indications, and Limitations."