Pressure Sensor Patch

Design Document

Team 12

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Executive Summary

People who have experienced significant damage to the lower extremities or suffer from disabilities affecting the lower extremities often are unable to feel when they are sitting with incorrect posture. Sitting with incorrect posture for long periods can develop pressure sores on the sit bones, which can be life-changing or even fatal in extreme cases. We are creating a pressure-sensing device alongside an app that can alert users when they may develop a pressure sore. Based on this information, we needed to create a system that is comfortable to sit on, does not cause additional friction, has sufficient battery life for average use, detects an imbalance in pressure, and sends out timely notifications of imbalance in pressure.

Our design includes using load cells (often used in scales to measure weight) and a pad where measurements can be taken. These measurements are then fed through an algorithm to detect whether or not the user needs to adjust position. We have created a functional prototype of a firm cutting board with four cut-out squares where load cells are placed for measuring weight. These cells are connected to an amplifier, which sends the signals to a Raspberry Pico W that sends the data over a wireless network. The Android application connects to this network, displaying the read data to a graph on the Android device.

This initial prototype lays a strong foundation where we can continue to design, develop, and test our system through an iterative approach. To further meet the design requirements, we need to implement a comfortable seat where the user can sit.
Our app must implement the cumulative sliding window streaming mean algorithm, where we calculate the read data and decide to send out a notification to the user. The app will also need a minor UI overhaul to improve the user experience.

Learning Summary

Development Standards & Practices Used

- ISO/IEC/IEEE International Standard - Software and systems engineering - Software testing – Part 2: Test processes
- ISO/IEC/IEEE International Standard - Systems and Software Engineering--Life Cycle Management--Part 5: Software Development Planning
- IEEE 802 Nendica Report: Flexible Factory IoT: Use Cases and Communication Requirements for Wired and Wireless Bridged Networks

Summary of Requirements

- The device does not cause additional friction
- Comfortable to sit on
- Sufficient battery life for average use
- Detects an imbalance in pressure
- Timely notifications of imbalance in pressure
- Wireless connection between app and device
- Functional for different types of adaptive sports equipment
- Easy for the user to set up the system by themselves
- Water-resistant

Applicable Courses from Iowa State University Curriculum

- CPRE 2880
- COM S 3090
- COM S 2270
- COM S 2280
- SE 3390
- CPRE 4190
- CPRE 4140
- COM S 3110
- COM S 3190
- EE 2010
- EE 2300
- CPRE 4890
- CPRE 3880
- CPRE 1850

New Skills/Knowledge acquired that was not taught in courses

- Kotlin programming language and modern Android application development
- 3D Modeling, 3D Scanning, 3D Printing
- Soldering

Table of Contents

List of figures/tables/symbols/definitions (This should be the similar to the project plan)

1. Introduction

1.1. Problem Statement

People with disabilities often need special equipment to do things that most people can do easily. With modern technology, doing things like playing sports, skiing, and rock climbing are no longer out of reach for people with disabilities. Even with advancements in this area, there are still some issues that can make activities like this problematic for people with disabilities. One of these potential problems is pressure sores. Pressure sores occur when there is too much pressure or an imbalance of pressure on some body part. Pressure sores can develop within minutes, and for people who are partially paralyzed or have missing limbs, it can be very hard to know when they may be at risk of developing one. Pressure sores can potentially become so severe that they are life-altering or life-threatening. For someone who is disabled and does not have an effective way of preventing pressure sores, this can become a constant worry when going out and doing things that are more physically demanding. For people like this, a device that can monitor pressure in areas where they cannot feel it is almost necessary; however, such a device does not yet exist.

1.2. Intended Users

a. Individuals with Adaptive Equipment

Disabled individuals who use adaptive equipment often need to abandon their standard tools to participate in physical activities like sports. These users frequently experience challenges due to a lack of sensation or nerve damage in certain parts of their body, making it difficult to detect excess pressure. Additionally, they may have missing limbs or be paralyzed, further complicating their ability to monitor physical strain. To address these challenges, these individuals require a way to recognize excessive pressure on specific parts of the body, enabling them to play adaptive sports safely without a heightened risk of injury. They also need a reliable method to detect and act on preventable injuries before they escalate.

The benefits of a pressure-monitoring device are significant for this group. It enables users to accurately identify excess pressure on body areas with reduced sensation, fostering a safer experience during physical activities. Such a device also provides peace of mind, empowering users to participate in adaptive sports freely without constant fear of injury. Furthermore, it helps prevent pressure-related injuries that could lead to severe complications, enhancing overall well-being and quality of life.

b. Caregivers/Coaches for Adaptive Sports Athletes

Caregivers and coaches for adaptive sports athletes work with individuals with disabilities, helping them engage in sports safely. These professionals are trained to accommodate various needs and understand the risks and potential complications associated with adaptive sports. They require tools to assist individuals who may be unable to communicate or detect physical problems, ensuring that their players are taking adequate precautions to avoid injury. Additionally, caregivers and coaches need methods to encourage participation among those hesitant to engage in sports due to concerns about pressure-related injuries.

A pressure-monitoring device offers several advantages for caregivers and coaches. It allows them to assist athletes in detecting injuries related to pressure that they might not feel, ensuring the safety of their players during activities. By providing this level of support, caregivers can instill confidence in their athletes, enabling them to enjoy adaptive sports without undue worry. Moreover, such a device can help caregivers build trust with skeptical participants, encouraging broader involvement in adaptive sports.

c. Healthcare Providers

Healthcare providers specializing in disabilities play a critical role in ensuring patient safety and well-being. These professionals have the expertise to recognize when preventive measures are necessary and identify individuals at high risk of complications from pressure-related injuries. Providers need tools to help patients remain safe when outside their direct care, as well as new options to recommend to those interested in adaptive sports but hesitant due to the potential for injury. Additionally, they require methods to gather accurate data on patient activity to suggest appropriate preventive measures.

With a pressure-monitoring device, healthcare providers gain the ability to recommend practical solutions for individuals at risk of pressure sores that they cannot feel. This device enhances patient safety during high-risk activities and provides valuable data for healthcare professionals to analyze and use in creating customized treatment plans or preventive strategies. Ultimately, this technology empowers providers to better support their patients' active lifestyles while minimizing the risk of injury.

2. Requirements, Constraints, And Standards

2.1. Requirements & Constraints

Functional Requirements

- **Pressure Sensing**: The mat must detect and measure pressure levels across multiple zones of the lower extremities, providing real-time feedback.
- **Threshold-Based Alerts**: The system must notify the user when pressure exceeds a set threshold in any zone, helping prevent pressure sores.
    - Constraint: Alert within 5 seconds of threshold breach.
- **Wireless Connectivity**: The mat must wirelessly transmit data to a mobile app for remote monitoring.
    - Constraint: Bluetooth range of up to 10 meters.
- **Data Storage**: The app must store pressure data logs for post-use analysis, with at least 7 days of data retrievable at any time.
- **Multi-Zone Sensitivity**: The mat must distinguish between different pressure zones, allowing for precise monitoring of specific areas
    - Constraint: Minimum of 8 sensor zones across the mat.

Resource Requirements

- **Sensor Technology**: The mat must integrate pressure-sensitive sensor technology (e.g., Sensitronics Matrixarray, Load Cell) capable of detecting small changes in pressure.

    - Constraint: Detects pressure up to 100 lbs.
- **Power Source**: The system must be powered by a rechargeable battery that allows for continuous use.
    - Constraint: Minimum battery life of 8 hours.

- **Microcontroller**: The system must include a microcontroller that can process data from multiple sensors and handle wireless transmission (e.g., Arduino or ESP32).

Physical Requirements

- **Mat Dimensions**: The mat must be large enough to cover the typical area of use for the lower extremities.
    - Constraint: Minimum size 15 inch x 15 inch.
- **Portability**: The mat should be lightweight and foldable, allowing for easy transport and storage
    - Constraint: Total weight must not exceed 2 lbs.
- **Durability**: The mat must be durable and withstand regular use without sensor degradation
    - Constraint: Must function properly after at least 1000 hours of use.

Aesthetic Requirements

- **Low Profile Design**: The mat must have a thin, flexible design so it can be comfortably placed under the user's legs without causing discomfort
    - Constraint: thickness must not exceed 5mm.

- **Neutral Color Scheme**: The mat should be available in neutral colors to blend with different environments.

User Experiential Requirements

- **Ease of Setup**: The mat must be simple to set up and use, requiring minimal user interaction beyond placing it under the lower extremities.

- **Comfort:** The mat cannot cause extra pressure or friction on the skin.

- **Skin-Friendly Materials**: The surface of the mat must be made from breathable, hypoallergenic materials to avoid skin irritation during prolonged use.
- **Mobile App Interface**: The mobile app must be intuitive and provide clear, easy-to-read pressure data and alerts.
    - Constraint: The average user should be able to understand the app within 5 minutes of use.

UI Requirements

- **Real-Time Visualization**: The app should display real-time visual feedback of pressure distribution across the mat, allowing users to quickly identify problem areas.
- **Customizable Alerts**: Users must be able to set custom pressure thresholds and receive notifications tailored to their specific needs.
- **Pressure History Review**: The app must allow users to review historical data and trends to track how pressure distribution changes over time.

2.2. Engineering Standards

Engineering standards play a vital role in ensuring the safety, reliability, and compatibility of modern technologies, including home power systems, phone chargers, and electric vehicles. Among the IEEE standards reviewed, the "ISO/IEC/IEEE International Standard - Software and Systems Engineering - Software Testing -- Part 2: Test Processes" [1] provides comprehensive guidelines for software testing, making it directly relevant to projects involving both app and device development. Similarly, the "ISO/IEC/IEEE International Standard - Systems and Software Engineering—Life Cycle Management—Part 5: Software Development Planning"[2] outlines critical requirements and practices for effective software planning and management, aligning well with structured development workflows. In contrast, the "IEEE 802 Nendica Report: Flexible Factory IoT" [3] focuses on communication requirements in factory environments and is not applicable to non-industrial projects. Additionally, another team member highlighted the "ISO/IEC/IEEE International Standard - Systems and Software Integration,"[4] which emphasizes integration processes for systems and software. To integrate these standards, the project will prioritize software testing as a key component of the development process while leveraging an already established framework for software development planning and task management, ensuring compliance without requiring significant design modifications.

3 Project Plan

3.1 Project Management/Tracking Procedures

We are adopting both the waterfall and agile methodology. We are continuously developing the hardware alongside the software and testing each. The software relies on the data from the hardware, so it requires some waterfall thinking.

We are using GitLab to store all code related to the project. We plan on using the *Issues* feature in GitLab to break down things we want to do in small tasks. These issues can have branches created from them, keeping our code separate and helping to avoid conflicts. These issues are contained inside of Issue Boards, which keep track of the status. We currently use Discord for communication and providing updates.

3.2 Task Decomposition

To effectively achieve the project's objectives, we have broken the work into specific tasks and subtasks, taking into account current limitations and planning for future enhancements. This decomposition ensures that progress is measurable and dependencies are clearly managed across hardware, software, and testing phases.

On the hardware side, the first major task involves the selection and testing of load cell sensors. Various sensor types are evaluated to ensure accuracy and sensitivity, followed by rigorous performance testing under varying weight conditions. The second key task focuses on integrating the Raspberry Pi Pico W as the microcontroller for the project. The Pico W is programmed to process sensor inputs and configured to establish a Wi-Fi-based client-server model for transmitting data. In this setup, the Pico W serves as the server, broadcasting real-time pressure data, while the Android app acts as the client, retrieving and displaying the data. Additionally, we validate the reliability and speed of data transmission in this initial prototype using the Wi-Fi configuration. The third hardware task is the design and development of the physical mat, which involves creating sensor placements using CAD software and developing 3D-printed prototypes to house the sensors securely while ensuring durability.

For the software tasks, the first priority is developing an intuitive user interface for the Android app using tools like Figma or Android Studio. The app will include features such as graphing to visualize pressure distribution in real time. The next step is creating and integrating algorithms to analyze incoming sensor data, detecting imbalances and generating threshold-based alert notifications to prompt corrective action. Finally, the software team focuses on ensuring seamless Wi-Fi data transmission between the Pico W server and the app client. This involves testing real-time data updates and measuring latency to ensure the system functions effectively.

Testing and validation are critical components of the project. Unit testing ensures the functionality of individual components, such as sensors, Wi-Fi modules, and app UI features. Integration testing combines the hardware and software systems to validate end-to-end functionality, simulating multiple scenarios like varying user weight and pressure distributions. System testing involves user simulations, with individuals sitting on the prototype mat to validate real-time data flow from sensors to the app, triggering notifications for detected imbalances.

To structure progress effectively, the project is divided into four Agile sprints. The first sprint focuses on the initial hardware setup, including sensor integration with the Pico W and the establishment of basic server functionality. The second sprint emphasizes app interface development and establishing seamless Wi-Fi communication. The third sprint integrates real-time data visualization, alerting features, and comprehensive testing. The final sprint is dedicated to user testing, refining the prototype, and gathering feedback to guide future iterations.

This task decomposition reflects the project's current reliance on Wi-Fi capabilities for the first prototype, while also planning for potential future enhancements, such as the integration of Bluetooth functionality.

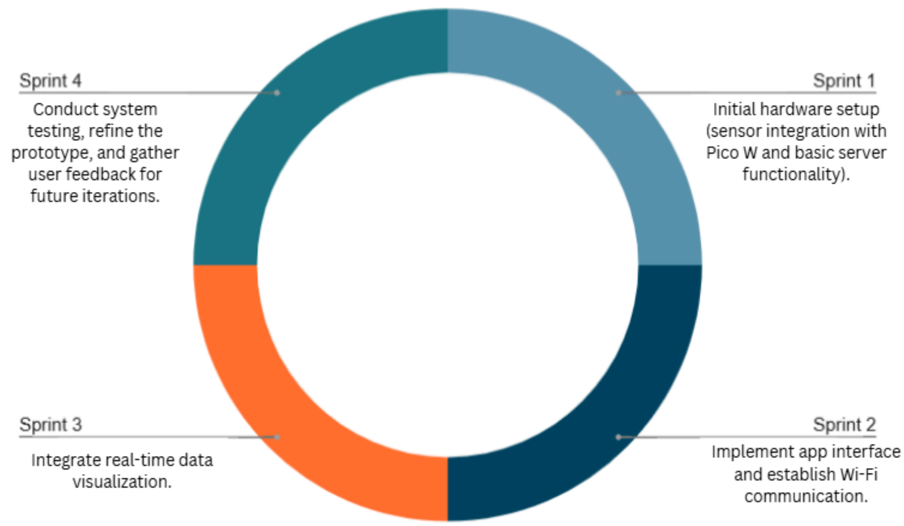

Figure 3.2.1 Progression with Agile Sprints

3.3 Project Proposed Milestones, Metrics, and Evaluation Criteria

Our project milestones are designed to align with the key tasks outlined in the decomposition, with measurable metrics to evaluate progress effectively. For hardware development, a primary milestone involves finalizing the selection and integration of load cell sensors. These sensors must detect pressure variations with at least 95% accuracy and respond to pressure changes within 1 second. Additionally, programming the Raspberry Pi Pico W as a server to process and transmit sensor data via Wi-Fi is another critical milestone. This functionality will be evaluated based on its ability to maintain a stable data transmission range of 10 meters with a latency of under 200 milliseconds and an uptime of 99% during continuous testing. The pressure sensor device design is also a priority, with targets to achieve a maximum thickness of 5mm for user comfort and a durability benchmark of 1000 hours of simulated use while supporting up to 100 lbs per load cell.

On the software side, key milestones include the development of a real-time pressure data visualization interface within the Android app. This will be measured by user testing to ensure that users can navigate the app and interpret visualizations within 5 minutes. The app will also be expected to update pressure readings every second or less. Another significant milestone is the implementation of the pressure imbalance detection algorithm, which must correctly identify imbalances in 95% of test cases and deliver notifications within 5 seconds of detection. Ensuring seamless Wi-Fi data transmission between the hardware and the app is also critical, with metrics focusing on connection stability for at least 8 continuous hours and minimal data loss in at least 95% of transmission tests.

Testing and validation milestones encompass unit, integration, and system-level testing. All individual system components will undergo rigorous unit testing, with an expectation of 100% coverage for critical functions. Integration testing will validate seamless data flow from load cells to the app through the microcontroller, with a performance benchmark of handling at least 10 simultaneous readings without delays. Finally, system testing will involve user feedback to ensure the prototype meets real-world usability and accuracy requirements. Feedback from at least five test users should indicate a satisfaction rate of 90% or higher, and all critical issues identified during testing must be resolved before final deployment.

As we follow an agile development process, these milestones and metrics will be refined at the end of each sprint based on feedback and iterative testing. This approach ensures adaptability and continuous improvement throughout the development cycle.

3.4 Project Timeline/Schedule

A well-structured timeline has been developed to guide the progress of our project. It is based on the tasks and subtasks outlined in **Task Decomposition (3.2)** and follows a hybrid approach incorporating elements of both Waterfall and Agile methodologies. The timeline has been divided into sprints, with clear milestones and deliverables associated with each sprint. To visualize this schedule, a Gantt chart has been created to represent the distribution of tasks, subtasks, and their respective deadlines. This chart also annotates the expected delivery dates for each project milestone.

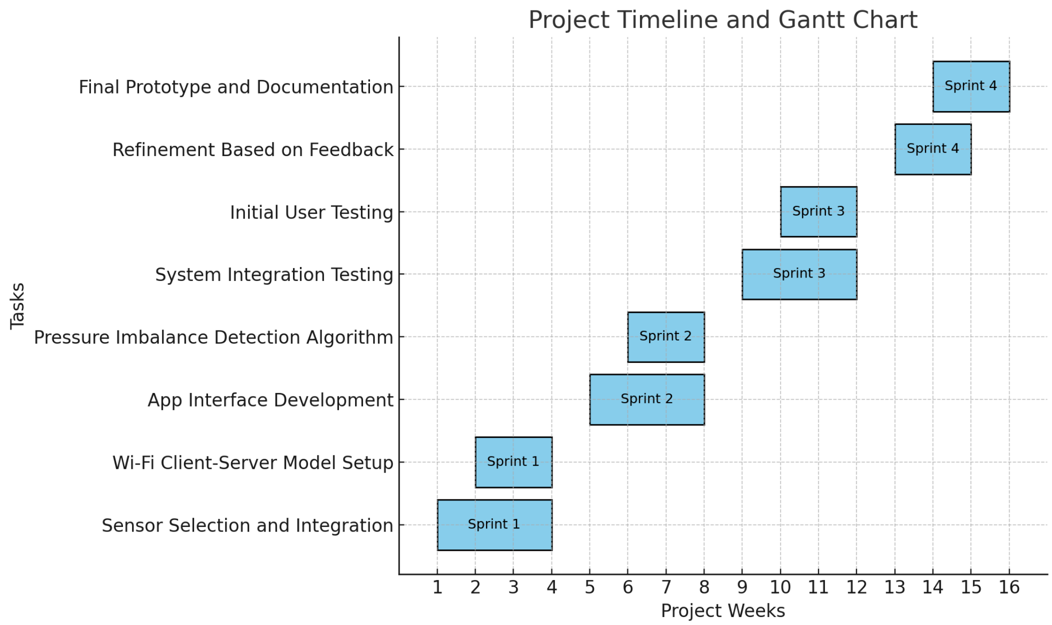

Figure 3.4.1 Project Timeline and Gantt Chart

Project Schedule Overview

The project spans a total of 16 weeks, divided into four sprints, each lasting four weeks. Each sprint focuses on specific components of the project to ensure iterative progress and consistent integration of hardware and software.

Sprint 1 (Weeks 1–4): Hardware and Initial Setup

- Key Tasks: Finalize sensor selection and integration with the Raspberry Pi Pico W. Develop the Wi-Fi client-server model to enable basic data transmission.
- Deliverables: Functional prototype capable of detecting and transmitting pressure data over Wi-Fi.

Sprint 2 (Weeks 5–8): App Interface and Data Processing

- Key Tasks: Implement the app interface with basic real-time visualization features.
- Deliverables: An app capable of displaying live pressure data.

Sprint 3 (Weeks 9–12): System Integration and Testing

- Key Tasks: Conduct integration testing between hardware and software components, ensuring seamless data flow and stability. Perform initial user testing to gather feedback on the prototype.
- Deliverables: A fully integrated system with consistent data transmission, live visualization, and reliable notifications.

Sprint 4 (Weeks 13–16): Refinement and Final Prototype

- Key Tasks: Address user feedback, refine both hardware and software components, and optimize performance. Prepare final documentation and presentation.
- Deliverables: A polished, user-ready prototype and final project report.

3.5 Risks and Risk Management/Mitigation

1. **Sensor Performance and Compatibility**

- Risk: Sensor accuracy may fall below the required resolution, or selected sensors may not be compatible with the microcontroller.
- Probability: 0.4
- Severity: Moderate
- Mitigation Plan:
    - Alternative Task: Source higher sensitivity sensors or develop signal-processing code to filter noise.
    - Off-the-Shelf Solution: Purchase a more robust, commercially available sensor with known compatibility.
    - Alternative Technology: Test multiple microcontrollers to assess compatibility.

2. **App Functionality and User Experience**

- Risk: App may not maintain alerts when closed, impacting user responsiveness.
- Probability: 0.5
- Severity: High
- Mitigation Plan:
  - Alternative Task: Investigate background service management for persistent notifications on Android.
  - Off-the-Shelf Solution: Leverage frameworks or libraries specifically designed for background task persistence.
  - Alternative Technology: Explore Power BI's real-time alert capabilities to assist in app functions.

3. **Scheduling and Agile Sprints**

- Risk: Delays in sensor testing may impact agile sprint progress and affect overall schedule.
- Probability: 0.4
- Severity: Moderate
- Mitigation Plan:
  - Alternative Tasks: Extend sprints by a week to accommodate testing and identify alternatives that might bypass delay factors if necessary.

3.6 Personnel Effort Requirements

Task	Number of Hours Required	Details
Hardware Integration	120 hours	• Need to find the right hardware. • Need to find how to integrate the chosen hardware.
Mobile App Development	160 hours	• Need to develop

		User Interface (UI). • Need to connect wirelessly. • Need to develop the notification's logic.
Wireless Connectivity	40 hours	• Need to figure out how to use Bluetooth.
Data Processing	130 hours	• Need to figure out when to send a notification and what data will need to be sent.
Testing & Validation	80 hours	• Need to constantly test the implementation of hardware and software.

Figure 3.6.1 Project Effort Estimates

3.7 Other Resource Requirements

1. Skill Acquisition

- Kotlin Programming: Team members will need to learn Kotlin to develop and maintain the Android app efficiently. Resources may include online courses, documentation, and tutorials.

2. Development Tools and Software

- Android Studio: Primary IDE for developing and testing the Android app.
- Database Systems: Any databases or cloud storage services needed for storing and retrieving user data and sensor readings.

3. Testing Equipment

- Debugging and Testing Devices: Access to Android devices (phones or tablets) for testing the app's functionality and real-time sensor data alerts.
- Simulators: Android emulators or simulators for testing different device environments and Android versions.

4 Design

4.1 Design Context

4.1.1 Broader Context

The design of our pressure-sensing device is situated within the broader context of improving accessibility and safety for individuals with disabilities, particularly in the realm of adaptive sports and physical activities. The primary communities we are designing for include individuals with disabilities who use adaptive equipment, such as wheelchair users, athletes with nerve damage, or those with limited mobility. These individuals often face challenges in detecting excessive pressure on their bodies, especially in areas with reduced sensation, which can lead to serious health complications like pressure sores. The project also directly impacts caregivers, coaches, and healthcare providers who are involved in supporting these individuals. By addressing the need for a tool to monitor and prevent pressure-related injuries, our design provides an invaluable resource to enhance the safety, independence, and quality of life for this community.

Area	**Description**	**Examples**
Public health, safety, and welfare	This project enhances the well-being of individuals by addressing risks related to pressure sores and promoting safer participation in physical activities for individuals with disabilities.	Reducing the risk of pressure sores for wheelchair users, preventing avoidable injuries, improving the safety of adaptive sports participants.
Global, cultural, and social	The design supports values of inclusion and equity by providing tools that empower individuals with disabilities to	Promoting accessibility in adaptive sports, reflecting global values of disability rights, enhancing inclusivity and social participation.

	participate in adaptive sports safely and confidently.	
Environmental	The project aims to minimize its environmental impact by using sustainable materials and energy-efficient design practices, ensuring the product is eco-friendly.	Using hypoallergenic and eco-friendly materials, reducing waste by using rechargeable batteries, minimizing environmental footprint through sustainable production practices.
Economic	The project is designed to be affordable for the target users, while also providing long-term economic benefits by preventing costly health complications and improving the quality of life.	Making the device affordable for individuals with disabilities and healthcare providers, reducing medical expenses from pressure sores, creating economic opportunities in the adaptive sports sector.

Figure 4.1.1 Project Design Considerations

4.1.2 Prior Work/Solutions

The development of our pressure-sensing device builds on a growing body of research and existing products in the field of pressure monitoring systems for individuals with disabilities. These products and studies have laid a solid foundation for understanding the challenges and opportunities in this domain. Below, we detail three relevant prior works, evaluate their advantages and shortcomings, and compare them to our proposed solution.

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1. **TekScan CONFORMat System [5]**

The TekScan CONFORMat system is a state-of-the-art pressure mapping solution designed for seating and positioning analysis. It provides real-time pressure distribution data and tracks the Center of Force (CoF) trajectory, making it a valuable tool for optimizing wheelchair seating systems. The system boasts over 2,000 sensing elements, delivering high-resolution data that can inform treatment decisions and improve cushion selection. Additionally, it uses vivid visual displays to engage patients and identify asymmetries or pelvic obliquities.

2. **TekScan Body Pressure Measurement System (BPMS) [6]**

The BPMS is an advanced pressure measurement tool designed for optimizing seating, bedding, cushioning, and positioning solutions. It is widely used in clinical and research settings to reduce the incidence of pressure sores, ulcers, and tissue deterioration. The ultra-thin, flexible pressure mapping matrix provides high-resolution data, enabling precise identification of anatomical structures causing concentrated pressure.

3. **TekScan F-Socket System [7]**

The F-Socket system is a high-resolution pressure mapping tool tailored for orthotists and prosthetists to enhance the design, fit, and functionality of prosthetic limbs. It uses ultra-thin sensors to measure pressure within the socket interface, providing valuable insights for optimizing socket-stump interfaces and improving user comfort and compliance.

Comparison and Differentiation

Solution	Pros	Cons
TekScan CONFORMat	High-resolution mapping for precise identification of pressure points. Portable and lightweight, allowing easy mobility between users and facilities. Useful for research and clinical justification for treatment decisions.	Expensive, limiting accessibility for individual users. Does not integrate with mobile applications, reducing usability in dynamic, real-world contexts.
TekScan BPMS	Captures detailed measurements of location	The BPMS is prohibitively expensive, making it

	and magnitude of peak pressures.	inaccessible for many users.
	Helps reduce the risk of pressure sores and accelerates healing.	Designed primarily for bed-bound patients, limiting its applicability for individuals using wheelchairs or participating in adaptive sports.
	Provides biofeedback, enabling tangible and visible insights for clients and clinicians.	Lacks integration with mobile applications for real-time feedback in dynamic environments.
TekScan F-Socket	Paper-thin sensors can be tailored to fit various prosthetic designs.	Expensive, limiting its accessibility to clinical or research settings.
	Provides detailed graphical displays and quantitative analysis of pressure distribution.	Focused solely on prosthetics and not applicable for dynamic seating environments or adaptive sports.
	Improves socket longevity and enhances user comfort.	Requires advanced expertise for setup and operation, making it less practical for everyday use by individual users.
Our Solution	Affordable	Still in prototype phase, currently reliant on Wi-Fi (future Bluetooth integration planned)
	Real-time alerts	
	Mobile app integration	
	Designed for adaptive sports and dynamic use	

Figure 4.1.2 Comparison of solutions

Our solution bridges the gap between existing systems by offering a **cost-effective, portable, and mobile-integrated pressure monitoring solution** tailored for wheelchair users and adaptive sports participants. Unlike the BPMS and F-Socket systems, which are either too specific or inaccessible for everyday use, our device prioritizes dynamic, real-world usability with a focus on affordability and inclusivity.

4.1.3 Technical Complexity

Our project demonstrates sufficient technical complexity through its multi-component design and the challenging requirements it addresses. The system incorporates distinct hardware and software subsystems, each requiring the application of various scientific, mathematical, and engineering principles. Furthermore, the problem scope involves multiple challenging requirements that aim to match or exceed current industry solutions in accessibility, usability, and effectiveness. Below, we provide a detailed breakdown of the technical complexity.

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1. **Multi-Component Design**

Hardware Subsystem

a. **Load Cell Sensors:**

- Utilizes strain gauge principles to measure changes in electrical resistance caused by pressure. This requires precise calibration to ensure accurate and reliable readings across a wide range of user weights and seating conditions.
- Challenges include accounting for sensor drift and ensuring uniform data across multiple sensors integrated into the seating surface.

b. **Raspberry Pi Pico W:**

- Acts as the central processor for collecting and transmitting data via a Wi-Fi-based client-server model. This involves integrating hardware communication protocols and ensuring low-latency, reliable data transmission to the software subsystem.
- Requires programming in MicroPython to handle real-time data processing and transmission while maintaining system stability.

c. **Physical Pressure Sensor Device:**

- Designed using principles of mechanical engineering and material science to ensure durability, comfort, and optimal placement of sensors. The thin, flexible device must withstand prolonged use while maintaining accuracy in pressure detection.

Software Subsystem

a. **Mobile Application:**

- Developed using Android Studio, the app uses user interface (UI) design principles to present real-time pressure distribution as a heatmap or graph.
- Challenges include ensuring smooth data visualization with minimal latency and developing a user-friendly interface accessible to individuals with varying technical proficiency.

b. **Threshold Detection Algorithm:**

- Applies mathematical models to analyze real-time pressure data, detecting when pressure levels exceed safe thresholds. This involves setting dynamic thresholds based on user profiles and optimizing the algorithm to reduce false positives.
- Challenges include defining safe thresholds for pressure sores without direct access to clinical expertise, which adds complexity to the algorithm design.

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2. **Problem Scope and Challenging Requirements**

Our project addresses several challenging requirements that match or exceed the current industry standards:

a. **Real-Time Monitoring:**
The system provides real-time updates with minimal latency, a key requirement for adaptive sports participants. Achieving this requires optimizing both hardware (sensor responsiveness) and software (efficient data processing).

b. **Portability and Comfort:**

Unlike existing solutions that are bulky or limited to clinical environments, our system is designed for dynamic, real-world use. This involves engineering a lightweight and unobtrusive device while maintaining accuracy and durability.

c. Affordability

One of the most challenging requirements is ensuring the system remains cost-effective for individuals with disabilities. This necessitates careful selection of components and efficient system design to minimize production costs without compromising functionality.

d. Wi-Fi Integration:

Implementing a Wi-Fi-based client-server model for seamless data transmission between the hardware and app involves challenges such as maintaining connection stability, optimizing power consumption, and ensuring scalability for future Bluetooth integration.

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3. Scientific, Mathematical, and Engineering Principles Applied

a. **Scientific Principles**: Strain gauge mechanics (load cells), material science (device design), and wireless communication protocols (Wi-Fi).
b. **Mathematical Models:** Signal processing for pressure data, real-time algorithm optimization, and statistical analysis for calibrating thresholds.
c. **Engineering Applications**: Embedded system programming (MicroPython for Pico W), mobile app development (Java/Kotlin for Android Studio), and mechanical design for sensor housing and device durability.

4.2 Design Exploration

4.2.1 Design Decisions

a. Sensor Type and Configuration

Choosing the type and configuration of sensors is critical, as it directly impacts the accuracy and responsiveness of the pressure readings. In this project, load cell arrays have been selected for its ability to detect small changes in pressure across different contact points and have a relevant range weight up to 110 pounds for every load cell. This decision ensures that users receive timely alerts for any potentially harmful pressure levels, making it central to the effectiveness and efficiency of the device.

b. Data Transmission Method

The decision to use Bluetooth for data transmission (instead of WiFi) is based on considerations of energy efficiency, ease of use, and compatibility with mobile devices. Bluetooth's lower energy consumption makes it ideal for wearable devices, extending battery life and reducing maintenance costs for users. Additionally, Bluetooth connectivity offers a simpler user experience for pairing the patch with a mobile app, ensuring the device remains convenient and user-friendly.

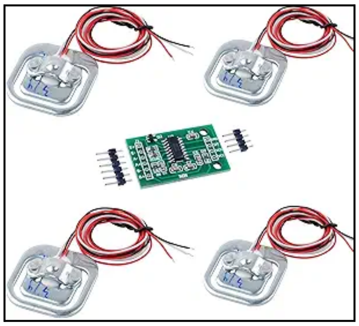
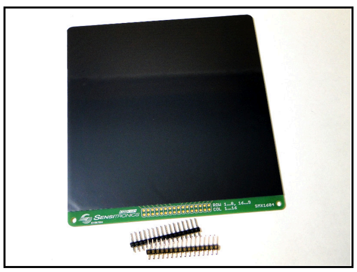
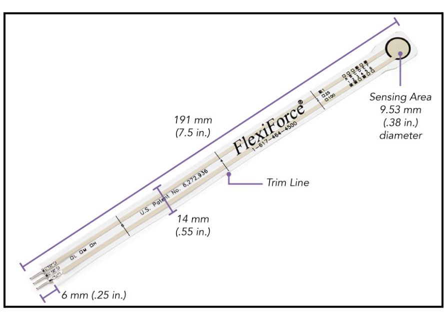
c. Mobile App Functionality and Interface

Deciding on an intuitive and accessible interface design for the mobile app is essential. The app's dashboard will display real-time pressure data and send alerts, ensuring that users can quickly interpret data and take corrective action if needed. This focus on user-friendly design helps ensure that the end product meets the needs of adaptive sports athletes and others at risk of pressure sores, increasing the likelihood of adoption and successful use.

4.2.2 Ideation

For the decision on **Sensor Type and Configuration,** we used **experimental prototyping** or hands-on comparative analysis techniques to explore potential sensor options. Below are the five options considered:

Potential Sensor Options	Explanation
1. **Load Cells**	Selected for their high load capacity of up to 110 pounds, which supports the range of body weights encountered in the

 *Figure 4.2.2.1 Load cells*	application. Each load cell is small (80 g) and compact, making it ideal for a wearable device. Often used in digital bathroom scales, this sensor is a half-bridge strain gauge, providing the precision required for monitoring body pressure effectively.
2. **ShuntMode MatrixArray**  *Figure 4.2.2.2 ShuntMode MatrixArray*	A rigid sensor array with 256 force-sensing cells arranged in a 16x16 grid, covering a 4x4 active area. Each cell can measure up to 50 lbs, making it suitable for multi-touch input and pressure mapping. However, its lack of flexibility and limited force range presented challenges for continuous body pressure sensing. This array requires additional soldering to connect to PCBs.
3. **FlexiForce A201 Sensor**  *Figure 4.2.2.3 FlexiForce A201 Sensor*	This sensor offers various lengths and a thin profile (0.203 mm) but has a small sensing area (9.7 mm diameter) that restricts its ability to cover larger surfaces. It has a standard force range of up to 445 N and operates in a broad temperature range (-40°C to 60°C), which is advantageous in various environmental conditions. However, its limited surface area was less practical for widespread skin contact

	monitoring, moreover for the adaptive sports athletes.
4. **Thin Film Pressure Sensor**  *Figure 4.2.2.4 Thin Film Pressure Sensor*	An affordable option with a maximum force capacity of 10 kg. This ultra-thin and flexible sensor responds rapidly to pressure changes and is both waterproof and sensitive. Although it offers high sensitivity and is well-suited for applications like wearables, its low maximum force limit made it less suitable for the project's needs.
5. **Thin Film Force Sensor (SF15-600)**  *Figure 4.2.2.5 Thin Film Force Sensor*	This flexible sensor emulates the perception capabilities of human skin, offering high sensitivity, quick response, and durability. It is resistant to bending and temperature fluctuations (-20°C to 60°C) and provides reliable performance. Despite its low price, its 10 kg limit was insufficient in supporting the required pressure ranges in this project.

4.2.3 Decision-Making and Trade-Off

To evaluate the different sensor options, we used a **weighted decision matrix** that considered key factors relevant to the project, including **load capacity**, **size and flexibility**, **power efficiency**, **cost**, and **durability**. Each criterion was weighted according to its importance to the project's success. Here is a breakdown of the decision-making process, followed by an explanation of why the load cell was ultimately chosen.

Weighted Decision Matrix

Sensor Option	Load Range (30%)	Size & Flexibility (25%)	Power Efficiency (15%)	Cost (15%)	Durability (15%)	Total Score
Load Cells	9	8	8	8	9	8.45
ShutMode Matrix Array	6	4	7	5	7	5.85
FlexiForce A201 Sensor	7	5	9	5	8	6.65
Thin Film Force Sensor	4	9	10	9	6	6.80
Thin Film Pressure Sensor	5	9	10	9	6	7.05

Figure 4.2.3.1 Weighted Decision Matrix

Decision Criteria and Weights

1. **Load Capacity (30%)**

   This is a critical criterion, as the sensor must be able to accommodate the pressure exerted by various body parts. Load cells scored highest here due to their wide range of up to 110 pounds, meeting the project’s requirements.

2. **Size & Flexibility (25%)**

Flexibility and compactness are essential for user comfort and integration into a wearable device. Thin film sensors performed well in this category due to their ultra-thin design, while load cells also scored reasonably well for their compact dimensions.

3. **Power Efficiency (15%)**

   Sensors must consume minimal power to extend the device's battery life. Thin film and FlexiForce sensors scored highly for low power consumption, but load cells also proved efficient enough for this application.

4. **Cost (15%)**

   Staying within budget is essential, especially as we tested multiple sensors. Thin film sensors had an advantage here with low prices, while load cells were slightly more expensive but still reasonable.

5. **Durability (15%)**

   Sensors need to withstand long-term use under various pressures. Load cells excelled in this category, as they are often used in scales and other applications requiring resilience.

Analysis and Choice

After scoring each option, Load Cells emerged as the highest-scoring sensor due to their broad load capacity, compact size, adequate power efficiency, and high durability. Although they were slightly more expensive than thin film options, their reliability in accurately measuring the necessary pressure range made them the best fit. The load cells provide stability and consistency, essential for ensuring that the device delivers accurate alerts to users, ultimately supporting the project's goal of effective pressure monitoring.

4.3 Proposed Design

4.3.1 Overview

Our pressure sensor patch is specifically designed to support adaptive sports athletes with nerve damage who may not feel pressure buildup and are unaware when pressure sores begin to develop, particularly on the lower extremities. For these athletes, monitoring pressure points is crucial since they may remain unaware of damaging pressure on certain areas due to impaired nerve function. The patch continuously tracks pressure levels and alerts the user if any area experiences excessive pressure for too long, allowing timely position adjustments to prevent sores.

This device is especially valuable for athletes in wheelchairs or those with limited mobility who frequently sit or place weight on specific parts of their lower body. By proactively alerting users when pressure thresholds are exceeded, the patch helps them prevent pressure sores before they become problematic, supporting a safer, more active lifestyle.

Key Components of the Pressure Sensor Patch

1. **Load Cell Sensors**

   These small sensors detect the amount of pressure applied to different areas where the patch is placed. They act like the pressure-measuring technology in digital bathroom scales, allowing us to monitor the force exerted on each sensor. By using multiple load cells, we can cover a larger area and get detailed pressure readings from different body parts.

2. **Microcontroller**

   The microcontroller is a small computer chip that processes the information from the load cell sensors. It takes in the pressure readings and checks if any of them exceed a safe threshold. If the pressure becomes too high, the microcontroller triggers a warning to alert the user.

3. **Bluetooth Connectivity**

   This feature allows the device to send pressure data wirelessly to a mobile app. With Bluetooth, users can view real-time pressure data on their smartphone, which also alerts them when adjustments are needed.

4. **Mobile App**

   The app provides a user-friendly interface that displays pressure readings from the sensors in real time. When excessive pressure is detected, the app sends an alert to the user, prompting them to adjust their position to relieve pressure. The app also logs pressure data over time, helping users and caregivers track patterns and identify areas that may need extra care.

How these Components Works Together

Our pressure sensor patch is specifically designed to support adaptive sports athletes with nerve damage who are unable to feel pressure and may not realize when pressure sores are developing, especially on the lower extremities. The device continuously monitors pressure levels through load cell sensors and sends this data to a microcontroller, which processes the readings and checks for any areas where pressure exceeds a safe threshold.

When excessive pressure is detected, the microcontroller initiates a response: it communicates with the app via Bluetooth to send an alert to the user's phone, and the mat itself produces a vibration or sound, giving an immediate and localized alert. This dual alert system—visual feedback from the app and sensory feedback from the mat—ensures that the user can quickly identify and relieve pressure on vulnerable areas, even without constant app monitoring.

This integrated design promotes user comfort and safety by offering real-time alerts and logging pressure data to track trends over time, helping prevent pressure sores before they develop. Lightweight, portable, and easy to use, the device is a practical tool that fits into an active lifestyle, providing peace of mind for athletes and their caregivers.

4.3.2 Detailed Design and Visual(s)

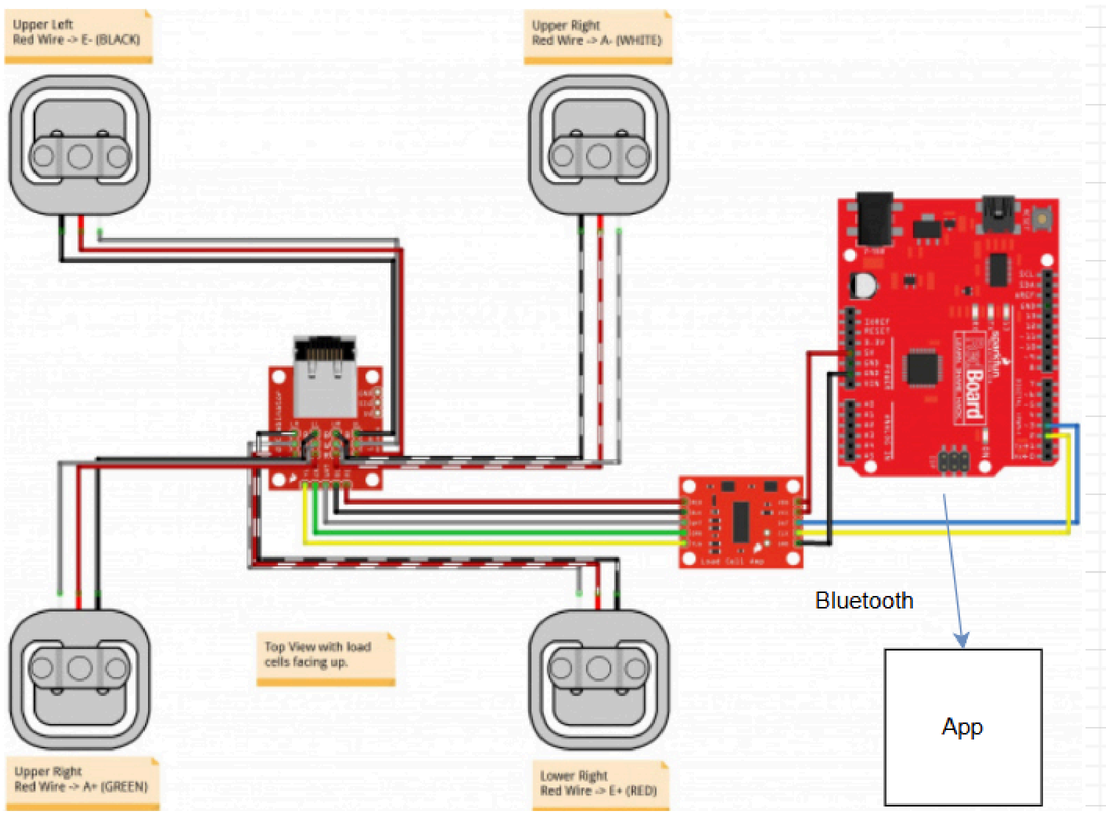
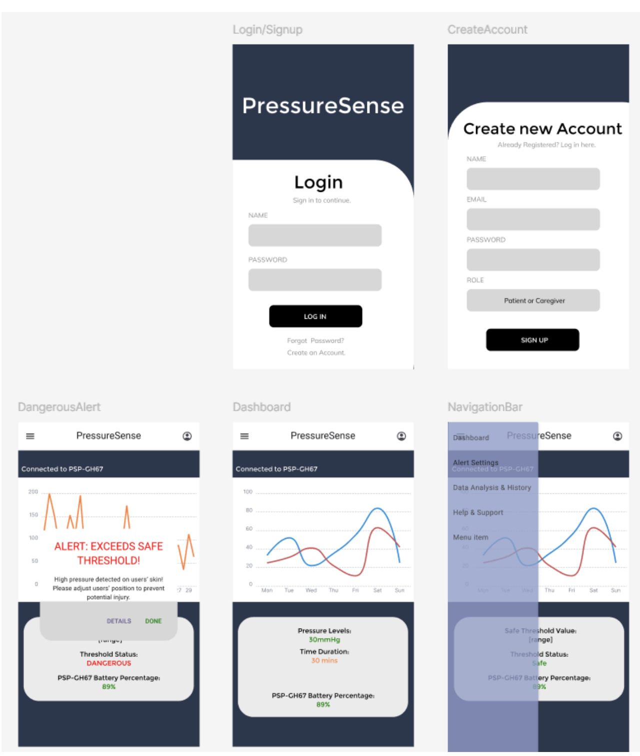


Figure 4.3.2.1 Hardware design schematic



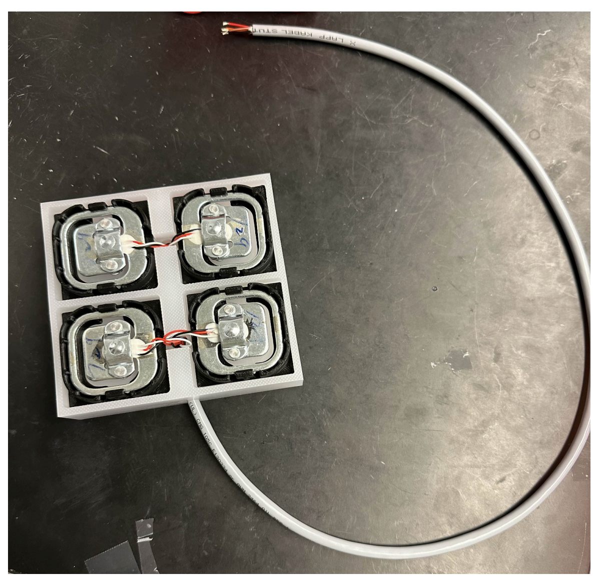


Figure 4.3.2.2 (left) and 4.3.2.3 (above)

Application Wireframe and Housing

Our design is split into two main components, the Android application and the pressure sensing hardware. The hardware consists of several components that allow relevant data to be collected and transmitted. In figure 4.3.2.1, a detailed diagram of the hardware components is shown. The silver objects in the corners are the load cells and they each use a mechanism known as a Strain Gauge. They are resistors in metallic z-shape strip form, shown in figure 4.3.2.4 below.

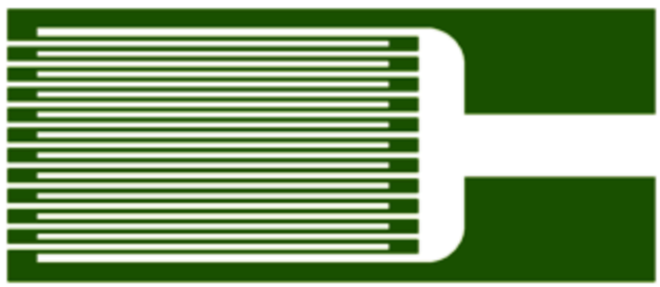


Figure 4.3.2.4 Strain gauge

They are capable of detecting small variable changes in resistance as deformation known as strain. A single load cell does not provide accurate measurement of applied force but four strain gauges in a wheatstone bridge circuit configuration can provide accurate and reliable force measurement as shown in figure 4.3.2.5 below

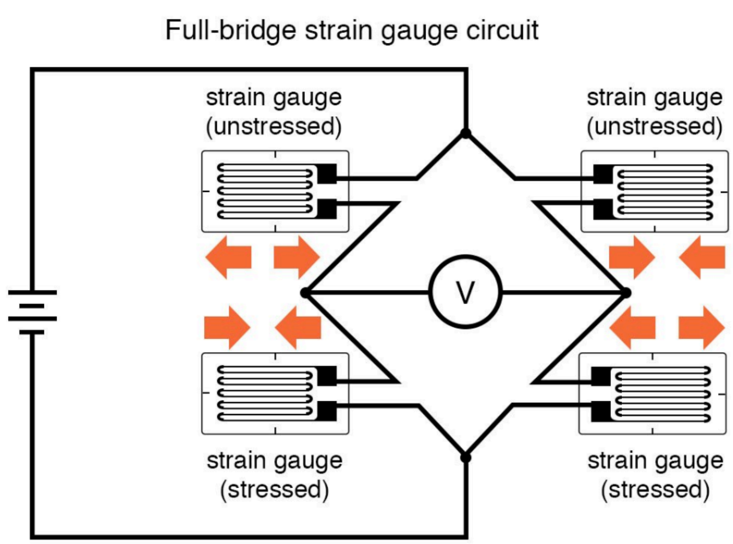


Figure 4.3.2.5 Strain gauge circuit

In this configuration there is a voltage applied to the 4 strain gauges creating a balance of resistance that is then unbalanced when a force is applied introducing a change in resistance to the gauges that can then be read from the circuit to measure the force applied accurately. Since each load cell has only one strain gauge, a separate hardware component known as a combinator allows for four load cells to be directly connected as shown in figure 4.3.2.1 to achieve the desired wheatstone bridge circuit that is needed. The output signal coming out of the combinator from the load cells is too weak to be directly given to the microcontroller for usable input, so instead the combinator is wired to a load cell amplifier. The amplifier first uses its internal Analog to Digital converter to process the analog signals coming from the combinator and transform them into digital signals. Then the amplifier strengthens the digital signal to be adequate for the microcontroller to process. The amplifier is then wired to a microcontroller with wireless communication capabilities. The microcontroller will then wirelessly transmit the received signal to an Android application.

The Android application receives the signal wirelessly from the microcontroller in the hardware system. Aside from this the Android application will include a user interface similar to the wireframe shown in figure 4.3.2.2, designed to make the application easy and pleasant to use. Standard user features will be available such as a login and signup allowing the user to view previous data or incidents on different devices. The application will also include a real time graph, that when connected will show the weights of all currently active pressure sensors. This graph will allow users to see a potential imbalance in real time and adjust themselves accordingly. If the user does not notice the imbalance, a notification system will be implemented. The notification system will use streaming algorithms to watch for a potential imbalance and ping the user if one is detected. This system will run in the background of the device, allowing the user to receive notifications even when they are not using their mobile device.

Another sub component of the system will be the housing. The load cells, combinator, and amplifiers will be placed into a secure housing as shown in figure 4.3.2.3, which will protect the circuits from damage as well as provide a flat surface for accurate readings from the load cells. These housings are meant to be placed under a seat where the user can still remain comfortable while gathering much needed information.

4.3.3 Functionality

Our pressure-sensing device is designed to assist individuals with disabilities in monitoring and managing pressure distribution while using adaptive equipment, such as wheelchairs or custom seating. The device operates seamlessly in real-world contexts, such as during prolonged sitting or participation in adaptive sports, and provides users with timely feedback to help prevent pressure-related injuries.

User Interaction and Workflow

1. **Setup:**
   - The user begins by placing the pressure sensing device on their seating surface (e.g., wheelchair or sports chair). The device is lightweight and portable, designed for easy placement and removal.
   - Once the device is positioned, the user turns on the system, which automatically connects to the mobile application via Wi-Fi (Bluetooth for final product).
2. **Monitoring:**
   - The device's embedded load cell sensors continuously measure pressure distribution across different areas. This data is processed by the Raspberry Pi Pico W, which acts as the system's central processor and server.
   - The mobile app displays real-time pressure data as a heatmap or graph. This visual representation helps users understand which areas are experiencing higher levels of pressure.
3. **Feedback:**
   - The system compares the measured pressure levels to predefined safe thresholds. When the pressure in a particular area exceeds these thresholds, the app triggers a notification to alert the user.

    - The alert includes a message, vibration or sound, prompting the user to adjust their position or redistribute their weight to alleviate excessive pressure.
4. **Data Tracking:**
    - The app stores pressure data over time, allowing users or caregivers to review historical trends. This feature helps in identifying recurring patterns or risk areas that may require further adjustments or interventions.
5. **Adjustment and Actions:**
    - Based on the feedback, the user can take immediate action, such as shifting their weight, changing their seating position, or consulting with a caregiver for further assistance.

Real-World Situation Example

Imagine a wheelchair user seated during a prolonged sports activity. As the user moves and shifts their weight, the pressure sensing device continuously monitors changes in pressure distribution. At a specific point, the system detects excessive pressure on a vulnerable area, such as the lower back. The mobile app sends a notification, prompting the user to adjust their position. The user follows the prompt, redistributes their weight, and continues participating in the activity safely, reducing the risk of developing a pressure sore.

4.3.4 Areas of Concern and Development

We believe that our design will do very well with satisfying requirements and meeting user needs. We have asked many questions regarding use cases and areas of most concern, and have adjusted our design in accordance.

The biggest point of concern is creating a pad that can fit many of the seats used by the disabled athletes. We need to design a system that can fit on a wheelchair, bike, kayak, etc.

We have requested an example pad that the athletes often use when sitting down. We made contact with the client stating this very issue. Unfortunately, they responded stating they don't have a one-size fits all and the design needs to be flexible with multiple seats.

4.4 Technology Considerations

1. **Fusion 360** - We are using this software to create the CAD design of the sensor board that holds all of the load cells and other hardware. We also are using it to touch up the design of the cases that hold the individual load cells.

2. **Artec Scanner** - We are using an Artec Spider 3D scanner to reduce custom component design time and mitigate our lack of 3D modeling ability.

3. **Bambu X1**- We are using a Bambu 3D printer to print 3D replicas of brackets for our load cells.

4. **Android Studio** - We are using this to design and implement the app-side of the pressure sensor. Android studio provides lots of tools to build a complex UI, and interact with device hardware such as Bluetooth. This complexity can also be seen as a weakness, as you can do a lot with Android Studio and have nearly full control over the device.

5. **Figma** - Figma is an excellent design tool for designing the UI portion of the app as well as the general flow of the device. It provides lots of tools for designing complex UIs.

4.5 Design Analysis

The development of our pressure-sensing device has progressed through several critical stages, including the initial design, prototype implementation, and preliminary testing. The current status reflects a blend of successful milestones and challenges that have provided valuable insights for future work.

Progress Achieved So Far

1. **Hardware**:
   - The load cell sensors have been successfully integrated into the prototype, mounted on a stable base to ensure accurate pressure detection. Calibration tests have shown that the sensors can reliably measure pressure variations under typical usage conditions.
   - The Raspberry Pi Pico W has been programmed to act as a server for collecting and transmitting sensor data via Wi-Fi. Initial tests confirm that the microcontroller processes and sends data to the mobile app effectively.
   - A 3D-printed housing has been developed to securely hold the sensors in place, providing durability and ensuring alignment for optimal readings.
2. **Software**:
   - The Android app has been developed to display real-time pressure data. A basic visualization feature has been implemented, allowing users to monitor pressure distribution in real time.
3. **Testing**:
   - Preliminary unit and interface testing have validated the functionality of individual hardware components and the basic integration between the Pico W and the app. Data transmission tests indicate low latency and reliable performance under controlled conditions.

Evaluation of the Proposed Design

The proposed design from Section 4.3 has largely functioned as expected in terms of basic operations and real-time data transmission. However, a few areas require further improvement to meet the intended requirements fully:

- **Strengths**:
  - The sensor integration and data collection process has been robust, providing reliable pressure readings.
  - Wi-Fi communication between the hardware and app has been stable, supporting real-time updates.

  - The app's interface is user-friendly, even in its preliminary form, with effective visualizations and alerts.
- **Challenges**:
  - Sensor calibration for varying user weights and pressure ranges has proven more complex than anticipated, requiring additional iterations to fine-tune accuracy.
  - The current prototype is somewhat bulky due to the early-stage physical design, reducing portability and comfort.
  - Determining a safe threshold for pressure levels is particularly challenging. This difficulty arises from the lack of deep expertise within the team or available advisors on pressure sore risk factors and safe limits. Without a clear understanding, the algorithm's accuracy in predicting unsafe pressure conditions remains limited.

Implications and Future Work

Despite the challenges encountered, the overall feasibility of the design remains promising. The core functionality has been demonstrated successfully, and the issues identified are primarily related to refinement rather than fundamental flaws.

1. **Hardware Refinement**:
   - Redesign the physical pressure device to improve portability and comfort by using thinner materials and optimizing sensor placement.
   - Further calibrate the sensors to accommodate a wider range of users with varying body weights and seating habits.
2. **Software Optimization**:
   - Design the alert algorithm to send notifications when pressure levels exceed a predefined limit and further minimize false positives while maintaining sensitivity to real risks.
   - Expand the app's features, such as historical data visualization and user-configurable thresholds, to improve user engagement and utility.
3. **Comprehensive Testing**:

- Conduct more extensive system-level testing under real-world conditions to validate the device's reliability and usability.
- Gather feedback from intended users to guide further design improvements.

By addressing these areas, we aim to deliver a refined and fully functional product that meets all user requirements and aligns with the project's goals.

5 Testing

Testing is a vital aspect of our project, ensuring that the pressure-sensing device meets its functional, safety, and user experience requirements. Our testing strategy is designed to validate both hardware and software components individually and as an integrated system. Early and iterative testing plays a central role in identifying and resolving issues throughout the development process. This proactive approach minimizes risks and ensures that the final product is reliable and user-friendly.

Testing Philosophy and Challenges

Our testing philosophy emphasizes a user-centered approach, focusing on ensuring the device's accuracy, responsiveness, and ease of use for individuals with disabilities. The iterative nature of our testing aligns with the Agile development process, enabling continuous refinement of the prototype. A unique challenge in testing our system is simulating realistic use cases, such as prolonged periods of sitting with varying pressure distributions. Additionally, ensuring real-time communication between the hardware and the mobile app adds complexity, particularly in maintaining low latency and reliable Wi-Fi connections.

5.1 Unit Testing

The units being tested will be divided between the hardware components and the software components. On the software side, we will be testing all individual methods within the frontend Android UI code and all individual methods within the backend server code. These methods will be tested using modern unit testing frameworks such as Espresso Mockito and JUnit.

On the hardware side, we have 2 key components that will be tested. We have the load cell weight sensors and the wifi communication module. Both of these components will be tested separately using an external device. Outputs will be written to a console and verified manually to ensure the components will be functioning as expected. A program like Putty will also be used to test network communication and verify that the hardware can communicate with external devices.

5.2 Interface Testing

Software Interface:

Our software interface includes an Android application that connects to our pressure sensor device. To test our app, we will utilize unit tests, along with simulation testing through Android Studio. We will also test our wireless connection with a physical Android phone.

Hardware Interface:

Our hardware interface includes our pressure sensor device. To test our device, we will use weights to ensure that our load cells are reading weight accurately. We will also test that our device is sending data correctly and timely by printing the output to a console and analyzing the data.

5.3 Integration Testing

The critical integration path includes reading data from load cells, obtaining a wireless connection to send the data from the load cells, and analyzing and displaying the data in an app. To test the load cells reading data, we will write a program to send the data output to a console. To test the wireless connection from the sensor to the app, we will download our app to a physical Android phone and ensure that we can receive and display data.

5.4 System Testing

To test the entire system, we plan on having an individual sit on the device to collect and stream data wirelessly to our app. The app will process the data through Hodzic's algorithm for identifying an excess of pressure due to the individual's seating position. This event will trigger the app to display a notification to the individual communicating that they should shift their weight for an estimated recommended time.

5.5 Regression Testing

To ensure that any new additions do not break the old functionality, we will utilize our current unit tests, along with creating new unit tests to cover the changes. We will also test individual sections of the system at a time so that if there is an issue, we will know where it is coming from.

5.6 Acceptance Testing

To demonstrate that the design requirements, both functional and non-functional, are being met, we will test our application and pressure sensor device with real users and collect and analyze data to ensure that the system works as expected. We plan to send a finalized prototype with instructions to our clients so that they can test our system.

5.7 Results

Thus far, we have tested that our load cells can output data, we can send data from the pressure sensor device wirelessly, and that we can receive and display data from the device to our Android application. Through this testing of our device and application, we learned that we needed to calibrate our device to output correct weight data. We also learned that we will need to find a method to store our sensor's output data, as there will be too much to store locally on the device running the application.

6 Implementation

Currently we have successfully managed to implement a working weight sensor that will transmit data wirelessly. The wireless data is also read by an Android application and displayed in the form of a real time line graph that updates as more weight is applied. The figures shown below are the real implementations of the hardware device and the application thus far.

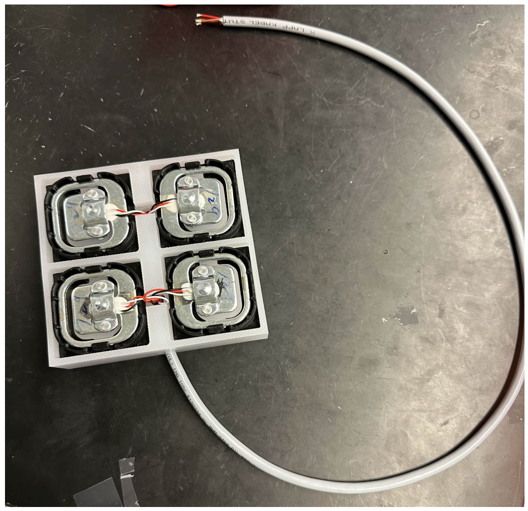


Figure 6.1.1 Hardware Component

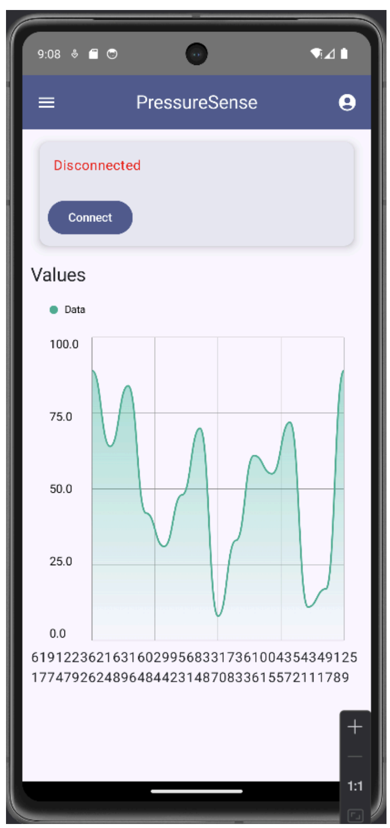


Figure 6.1.2 Android Application Component

7 Ethics and Professional Responsibility

In the context of this project, **engineering ethics and professional responsibility** are defined as the commitment to creating a design that upholds the safety, health, and well-being of its users while respecting societal, environmental, and economic considerations. Our team adheres to the principles outlined in the **IEEE Code of Ethics**, ensuring that the project is conducted responsibly, transparently, and with integrity. Ethical considerations permeate all aspects of our work, from designing for user safety to respecting client intellectual property and minimizing environmental impact.

The overarching ethical philosophy of our team is guided by the principle of "**beneficence with accountability.**" This means that while we strive to create a product that benefits users and society, we hold ourselves accountable for its safety, quality, and broader impact. To ensure this, we have implemented measures such as regular ethical reviews, adherence to established standards, and fostering a culture of continuous improvement.

By embedding these considerations into our workflow, we uphold the principles of engineering ethics and professional responsibility, ensuring that our project meets the highest standards of integrity and excellence.

7.1 Areas of Professional Responsibility/Codes of Ethics

Areas of Professional Responsibility

Area of Responsibility [8]	Definition	Relevant Item from Code of Ethics [9]	Team Interaction and Adherence
Work Competence	Perform work of high quality, integrity, timeliness, and professional competence	**IEEE Code of Ethics #6**: "Improve the understanding of technology and its application."	The team has consistently pursued skill development, including learning Kotlin and sensor integration techniques, to ensure technical competence.
Financial	Deliver products and	**IEEE Code of Ethics #9**:	The team has adhered to budget

Responsibility	services of realizable value and at reasonable costs.	"Avoid injuring others, their property, reputation, or employment by false or malicious action."	constraints by choosing cost-effective components, balancing affordability with functionality.
Communication Honesty	Reports work truthfully, without deception, and are understandable to stakeholders.	**IEEE Code of Ethics #3**: "Be honest and realistic in stating claims or estimates based on available data."	The team has provided regular updates to advisors and clients through progress reports and meetings, ensuring transparency.
Health, Safety, and Welfare	Minimize risks to safety, health, and well-being of stakeholders.	**IEEE Code of Ethics #1:** "Hold paramount the safety, health, and welfare of the public."	The team has designed the device to prioritize the prevention of pressure sores, reducing health risks for users.
Property Ownership	Respecting the property, ideas, and information of clients and other stakeholders.	**IEEE Code of Ethics #7:** "Treat all persons fairly and with respect, and to not engage in discrimination based on characteristics such as race, religion, gender, disability, age, national origin, sexual orientation, gender identity, or gender expression"	The team ensures the protection of client-provided data, design requirements, and intellectual property by using secure project repositories and agreements.
Sustainability	Protect environment and natural resources locally and globally	**IEEE Code of Ethics #1 and #2**: "Improve the understanding of technology's potential impact on society and the environment."	The team has incorporated eco-friendly materials and rechargeable batteries to reduce waste and environmental harm.
Social Responsibility	Produce products and services that benefit society and communities.	**IEEE Code of Ethics #4:** "Avoid unlawful conduct in professional activities, and to reject bribery in all its forms."	The project is designed to enhance inclusivity, ensuring individuals with disabilities can participate safely in adaptive sports.

Figure 7.1.1 Professional Responsibility Table

Team Performance Analysis

Area of Strong Performance: Health, Safety, and Welfare

The team excels in prioritizing the safety and well-being of the end users. By designing the device to monitor and prevent pressure sores, the project directly addresses a critical health concern for individuals with disabilities. Additionally, the team has implemented thorough testing protocols to ensure the reliability and safety of the device under various conditions. This focus on user safety demonstrates a commitment to adhering to the principle of holding paramount the health and welfare of the public, as outlined in the IEEE Code of Ethics.

Area for Improvement: Communication Honesty

While the team has maintained transparency in progress reports and regular updates, there have been occasional challenges in clearly articulating technical limitations and timelines to stakeholders. For example, delays in hardware testing due to unexpected integration challenges were not communicated immediately, leading to misaligned expectations with the advisors. To improve, the team plans to enhance communication practices by implementing a standardized reporting template that includes a detailed status update, identified challenges, and proposed resolutions. Additionally, scheduling regular check-ins with stakeholders to align on progress and expectations will ensure more effective and honest communication moving forward.

7.2 Four Principles

Broader Context Area [10]	Beneficence	Nonmaleficence	Respect for Autonomy	Justice
Public Health, Safety, and Welfare	The pressure-sensing system helps reduce the risk of pressure sores, improving overall health and well-being.	The device aims to prevent the harm caused by pressure sores, which can lead to serious health complications.	Provides individuals with disabilities the ability to take proactive control over their health by receiving alerts.	Ensures equitable access to health tools for those who need them, including individuals with limited resources.
Global, Cultural,	Promotes	By preventing injuries,	Empowers users to	Ensures that

and Social	inclusivity by enabling disabled individuals to participate in adaptive sports safely.	the product ensures that users can engage in activities without long-term harm.	decide when and how to take action regarding their health based on the real-time data.	adaptive sports can be accessed by individuals with disabilities, supporting equal opportunities.
Environmental	The use of eco-friendly materials ensures the design benefits the environment by reducing waste.	The design minimizes harmful environmental impacts by opting for sustainable materials and energy-efficient design.	Allows users to make environmentally conscious decisions, such as reducing waste by using rechargeable batteries.	Strives to use sustainable practices, ensuring the product is affordable without compromising environmental values.
Economic	Offers a low-cost, accessible solution for those at risk of pressure sores, promoting financial well-being.	Minimizes long-term healthcare costs by reducing the need for expensive treatments for pressure-related injuries.	The product enables users to make decisions about their participation in sports based on their health needs.	Makes the technology available to diverse socioeconomic groups, addressing disparities in healthcare access.

Figure 7.2.1 Guiding Principles Table

7.3 Virtues

Virtues our team will uphold include:

Honesty:

Honesty as a virtue requires that all individuals are honest in what they say and do. Individuals should not mislead others, or be intentionally deceitful. Our team will continue to be honest with our clients in what is realistically achievable within the given budget and current state of technology. Our team will continue to be truthful in what we have accomplished, and what we expect to accomplish.

Commitment to quality:

Commitment to quality dictates that an individual will strive to achieve a product that is at the highest quality they can achieve. Our group will support this virtue by striving to use state of the art technologies and frameworks to ensure our system is as modern as possible. We will also ensure that our system functions exactly as expected and eliminate any deficits that may exist in the system when possible to do so.

Clear and thorough documentation:

Clear and thorough documentation dictates that an individual must document their process in a way that others can clearly understand what was done and how any system is meant to work. Our group will support this virtue by creating documentation surrounding our system that will allow others to repeat our steps to create a similar system.

Osaid Samman:

- One virtue I have demonstrated in my senior design work thus far is cooperativeness.
    - Cooperativeness is crucial to me because it helps foster collaboration, ensures tasks are completed efficiently, and maintains harmony within the team. As the Scrum Master, it aligns perfectly with my responsibility to keep communication open and productive among team members, helping everyone work together effectively toward our goals.
    - I demonstrated cooperativeness by facilitating clear communication between team members, organizing regular Scrum meetings, and ensuring that everyone was aligned on our project goals and deadlines. By actively listening to feedback and addressing concerns, I created an environment where everyone felt heard and motivated to contribute their best.
- One virtue that is important to me that I have not demonstrated in my senior design work thus far is civic-mindedness.
    - Civic-mindedness is important to me because it involves understanding and contributing to the broader context of our work, including technical details and their potential societal impact. By being more aware of the technicalities my team members worked on, I could have better supported their efforts and ensured our project aligned with both technical excellence and societal needs.
    - To demonstrate civic-mindedness, I can take a more proactive approach to understanding the technical aspects of our project.

Ivan Alvarado-Santoy:

- A virtue that I have demonstrated thus far through my senior design project is kindness
    - This is important to me because without kindness, it is difficult to build a strong team relationship that is needed for a successful project and worthwhile experience.
    - I have demonstrated kindness by encouraging my teammates to share their ideas and concerns.
- One virtue that I hold as important but have not demonstrated in this project is reliability.
    - It is important to me because without being a reliable teammate, it is difficult to work effectively as a team and achieve the goals that we have set. I would not want my teammates to have doubt on me making our team meetings when I say I am going to be there but am not or do not communicate the progress of my work
    - I will demonstrate this virtue by prioritizing my team meeting times in my future schedule and planning accordingly with the team on when I can not attend meetings but make sure they are aware of the status of my work so as to not leave them in the dark of my progress.

Sabrina Francis:

- One virtue that I have demonstrated through my senior design work thus far is honesty.
    - This is very important to me because being dishonest can lead to many problems down the line.
    - I have demonstrated honesty by always being honest with our client and my team members and being transparent about project status, budget, and all other project related subjects.
- One virtue that I have not yet demonstrated through this project is clear and thorough documentation.
    - This virtue is important to me because having detailed documentation makes it much easier for both yourself and others to continue working on a project later on. It is also useful for when revisions or changes are being made to the design, so you can look back at previous documentation.

    - To demonstrate this virtue in the future, I could make an organized system for adding documentation on design details and changes to ensure all useful information about our project is being documented.

Zane Lenz:

- A virtue that I believe I have demonstrated is reliability.
    - Reliability is important to me because it brings me peace of mind to know that other people will get their tasks done, and I would be a hypocrite if I didn't try to hold myself to the same standard.
    - I believe I have shown it throughout the semester by attending nearly all meetings and lectures. In addition to that I think I have done a good job contributing to group assignments and getting my own project tasks done in a timely manner.
- A virtue I have been lacking in this semester has been communication.
    - It is vital to any project that everyone is on the same page and communication is the key to making that happen. With good communication problems can be avoided and better ideas could be implemented.
    - I think I could speak up a bit more in group meetings and contribute more to conversations with clients and advisors.

Bilal Hodzic:

- One virtue I have demonstrated thus far is commitment to quality.
    - This virtue is important to me as I believe that everyone should strive to produce the best product possible and should not become complacent when developing systems.
    - I have demonstrated this virtue by striving to ensure our codebase will be warning and error free, while also ensuring that we follow industry standard conventions and principles when working with software.
- One virtue I have not demonstrated is clear and thorough documentation.
    - This virtue is important to me as I believe that all systems should be able to be worked on by anyone with a similar skill set at any point in time.
    - To demonstrate this virtue I will strive to write accurate documentation within the code base, such as API documentation and comments throughout the codebase.

Nathan Turnis:

- One virtue I have demonstrated thus far is commitment to design.
    - This virtue is important to me because proper design helps to make a successful project. Designing an application where it is easy-to-use by the user is important.
    - To demonstrate this virtue I will create designs that are user-friendly and easy to understand. I need to design code that has good readability and reusability. Using common design principles and patterns instead of throwing things into one file.
- One virtue I have not demonstrated is clear communication.
    - This virtue is important to me because when there is effective communication, group members are knowledgeable on what I have been working on. I have not always been clear with what I have done or will do.
    - To demonstrate this virtue, I plan on updating the team more through our communication channels on what I have done so far and what I plan to do in the future. I plan on asking for constructive feedback which I can apply to my code.

Aina Azman:

- One virtue I have demonstrated in my senior design work thus far is clear and thorough documentation.
    - Clear and thorough documentation is important to me because it ensures that the process is transparent and easily understood by others. It helps maintain continuity in the project, and it ensures that the design, system and decisions are well-documented for future reference.
    - I have demonstrated this virtue by ensuring that all components of our project are well-documented, including the design decisions, code, and system requirements. I have also helped establish initial documents for documentation that allows all team members to access and contribute to the project details.
- One virtue I have not demonstrated in my senior design work thus far is clear communication.
    - Communication is critical because it ensures that the team is aligned, progress is tracked, and all team members are aware of any challenges or changes. It helps build a collaborative environment and reduces

misunderstandings. Without clear communication, it's difficult to stay informed about the overall project status and can lead to missed opportunities for improvement or collaboration.

- To improve communication, I plan to make a conscious effort to engage more frequently with the team, ask for updates, and share my progress openly. I will work on being more proactive in discussions, making sure I stay informed about what's happening with the project, and contributing regularly in meetings.

8 Closing Material

8.1 Conclusion

As of now we have succeeded in making one pressure sensing device that will communicate wirelessly with an android application to display real time data. The goals of this project were to make a pressure sensing device that will allow for a disabled user to monitor pressure on lower extremities in real time, transmit this data to an application where the user can see in real time their weight distribution, and notify the user of any imbalance of pressure thus actively preventing pressure sores. The best plan of action to achieve these goals will be first to develop working hardware that will accurately measure pressure, then create communication to display this information graphically to the user, and finally analyze this data coming in to alert the user in real time when they are at risk. So far we have achieved our first two goals of developing working hardware and displaying this data visually on an application, however due to time constraints we have not yet been able to effectively analyze the data coming in to provide relevant information to the user. In the future the work could be split up differently to allow for better use of group members thus accomplishing more faster.

8.2 References

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8.3 Appendices

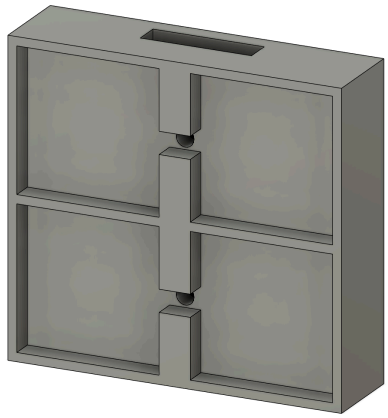

Figure 8.3.1 Hardware housing CAD Design

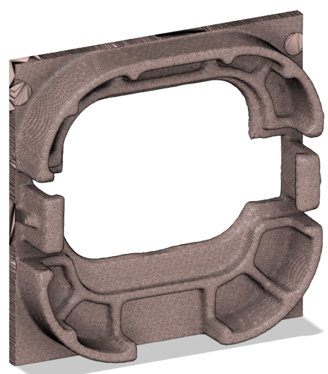

Figure 8.3.2 Load Cell Bracket CAD Design

9 Team

9.1 Team Members

1. Aina Qistina Binti Azman
2. Bilal Hodzic
3. Nathan Turnis
4. Osaid Samman
5. Sabrina Francis
6. Zane Lenz
7. Ivan Alvarado-Santoy

9.2 Required Skill Sets for Your Project

- Knowledge of Android Development
- Soldering
- 3D Modeling, 3D Scanning, 3D Printing
- Networking

9.3 Skill Sets covered by the Team

- Knowledge of Android Development
  - Aina Qistina Binti Azman
  - Bilal Hodzic
  - Nathan Turnis
- Soldering
  - Ivan Alvarado-Santoy
- 3D Modeling, 3D Scanning, 3D Printing
  - Sabrina Francis
  - Zane Lenz
- Networking
  - Osaid Samman

9.4 Project Management Style Adopted by the team

Typically, Waterfall or Agile for project management.

9.5 Initial Project Management Roles

Communications Manager - Osaid Samman

Hardware Manager - Ivan Alvarado-Santoy

Software Manager - Bilal Hodzic

9.6 Team Contract

Team Members:

1. Aina Qistina Binti Azman
2. Bilal Hodzic
3. Nathan Turnis
4. Osaid Samman
5. Sabrina Francis
6. Zane Lenz
7. Ivan Alvarado-Santoy

Team Procedures

1. **Day, time, and location (face-to-face or virtual) for regular team meetings:**
   Weekly Team Meetings will be on Sundays in the TLA at 2:00 PM
   Weekly Software Meeting: Wednesdays 1-2 pm. Virtual or In Person
   Weekly Hardware Meeting: Thursdays 7-8 pm. In-person (TLA)
   Client Team Meetings: Twice a month. Virtual meetings.
   Faculty Advisor Meetings: Friday 11-12pm

2. **Preferred method of communication updates, reminders, issues, and scheduling (e.g., e-mail, phone, app, face-to-face):**
   Discord for communication outside of meetings.
   Weekly in-person team meetings.

3. **Decision-making policy (e.g., consensus, majority vote):**
   Consensus, if possible; if not, then vote within 10-15 minutes.

4. **Procedures for record keeping (i.e., who will keep meeting minutes, how will minutes be shared/archived):**
   Discuss agendas, tasks, and what we've done during the Scrum Meetings, and it will be kept track of. Later, when tasks are more defined, we can have separate meetings between different groups.

Participation Expectations

1. **Expected individual attendance, punctuality, and participation at all team meetings:**
   Presence at weekly meetings is expected unless communicated ahead of time for being absent.

2. **Expected level of responsibility for fulfilling team assignments, timelines, and deadlines:**
   Each team member is fully responsible for completing their assigned individual work by the designated deadline, and teamwork assignments are to be broken up as needed. Any concerns for not meeting deadlines or need for help should be communicated ahead of time.

3. **Expected level of communication with other team members:**
   Respond to Discord messages within the same day, otherwise communicate as needed.

4. **Expected level of commitment to team decisions and tasks:**

All work must be completed by an agreed-upon deadline. If challenges/issues arise they must be communicated ahead of time to be resolved within a timely manner.

Leadership

1. **Leadership roles for each team member (e.g., team organization, client interaction, individual component design, testing, etc.):**

   1) **Aina Qistina Binti Azman -** Software Developer
   2) **Bilal Hodzic -** Software Lead
   3) **Nathan Turnis -** Software Developer
   4) **Osaid Samman -** Scrum Master/Manager/Team Organization
   5) **Sabrina Francis -** Hardware Developer
   6) **Zane Lenz -** Hardware Developer
   7) **Ivan Alvarado-Santoy -** Hardware Lead

2. **Strategies for supporting and guiding the work of all team members:**
   - Proactively communicating any challenges that might occur so the team is aware and can lend support as needed.
   - Starting work early.
   - Do your best not to procrastinate.

3. **Strategies for recognizing the contributions of all team members:**
   Task tracking to document those who completed the work.

Collaboration and Inclusion

1. **Describe the skills, expertise, and unique perspectives each team member brings to the team.**
   Aina: Prior experience with web/application development, unit testing. Experience in Java, C, C++, HTML/CSS, JS.

   Bilal: Prior experience with software web development. Experience in Java, C#, C, Python, HTML/CSS, JS.

   Nathan: Prior experience in software web app development. Experience in Java, C#, Python, HTML/CSS, JS. Experience in Android frontend development.

   Osaid: Prior experience with IT, Java, C, C#, HTML/CSS/JS, Embedded, Networking, Circuits.

   Sabrina: Prior experience with embedded programming and security. Experience in debugging, unit testing, and simulation testing. Experience in C, C++, Java, Python.

Zane: Prior experience with web development, automation, and embedded systems programming. Java, C/C++, Python, HTML/CSS, JavaScript

Ivan: Prior experience with writing and debugging code for hardware, Testing, Integrating hardware, soldering. Good with Linux/Unix, C/C++, Containers, and 3D printing

2. **Strategies for encouraging and supporting contributions and ideas from all team members:**
   - Listen and don't shoot down ideas right away.
   - Scheduled weekly meetings discussing future and current work, plus extra meetings if anyone needs help.

3. **Procedures for identifying and resolving collaboration or inclusion issues (e.g., how will a team member inform the team that the team environment is obstructing their opportunity or ability to contribute?)**
   - Make sure everyone has work to do in weekly meetings.
   - Reach out if any collaboration issues are noticed.
   - Make sure everyone enjoys the work they are doing.

Goal-Setting, Planning, and Execution

- **Team goals for this semester:**
  - App wireframes.
  - Select hardware components.
- **Strategies for planning and assigning individual and team work:**
  - Plan and assign work during weekly scrum meetings.
  - Estimate deadlines and try to have work done by then, no hard deadlines.
- **Strategies for keeping on task:**
  - Breaking tasks down to manageable components.

Consequences for Not Adhering to Team Contract

1. **How will you handle infractions of any of the obligations of this team contract?**
   Figure out what went wrong and try to help and fix it. Communication is key.

2. **What will your team do if the infractions continue?**
   Communicate the situation to the instructor.

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***

a) *I participated in formulating the standards, roles, and procedures as stated in this contract.*
b) *I understand that I am obligated to abide by these terms and conditions.*
c) *I understand that if I do not abide by these terms and conditions, I will suffer the consequences as stated in this contract.*

1) Osaid Samman	**DATE**	9/8/2024
2) Nathan Turnis	**DATE**	9/8/2024
3) Aina Qistina Binti Azman	**DATE**	9/8/2024
4) Sabrina Francis	**DATE**	9/8/2024
5) Bilal Hodzic	**DATE**	9/8/2024
6) Zane Lenz	**DATE**	9/8/2024
7) Ivan Alvarado-Santoy	**DATE**	9/8/2024