ParaPedal:
A Practical Product for Paraplegic Piano Players!

Engineers (Group 15):

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Electrical Engineering	Electrical Engineering	Electrical Engineering (Manager)	Electrical Engineering

Professor:

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Content

Motivation

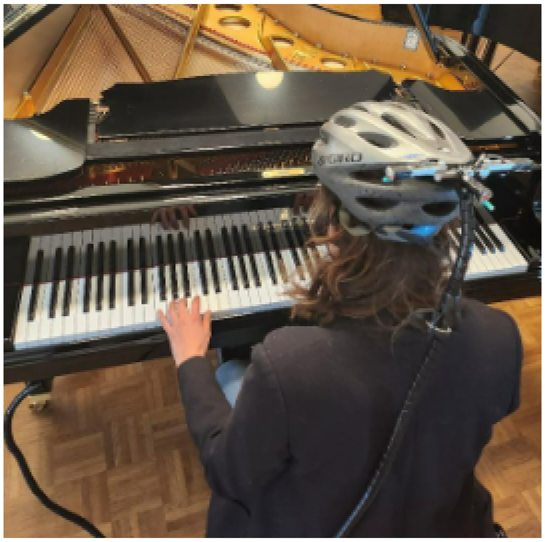
The Idea of building a piano assistance device for people in wheelchairs was inspired by one of our group members, Benedict Eberhagen. He learned how to play the piano at a young age, however he stopped for a while. More recently, he has been picking it back up. However, he is now playing with one major change - he is currently in a wheelchair. His progress working on and improving his piano playing has been going great. However, since he is now in a wheelchair and incapable of using his legs, he is unable to play most of his piano pieces properly, he is unable to activate the piano pedals at the bottom of the piano. Although the usage of pedals isn't necessary to play a piece successfully, it does enhance the quality and sound of the piano piece. With that, our motivation is to help Benedict play the piano properly once more, as well as helping other people with physical disabilities - paraplegics in particular - to be able to activate the foot pedal in an easy and intuitive way. Our product will help our target customers reach the full potential and range of sounds that a piano has to offer. Benedict is an intermediate-level piano player with a decent background in understanding how to play, but he is not at the professional level. Our build will be focused around that factor as well. We will design our device to be more beginner-level and intermediate-level friendly, instead of making it overly complicated and designed for professional-level play.

Background

Our team consists of 4 Electrical Engineers, so our main focus on this project will be on the hardware of the remote-activated piano pedals, instead of the software. Two of our members, Andre and Jason, already have a strong background in designing PCBs having worked with them in their jobs and during research. Rafael has worked quite a bit with power distribution and overarching electrical designs during his internships. Benedict has a good amount of experience on the software side of designing devices, which he worked on during his internships.

Existing products

There are already a couple of devices on the market that allow paraplegics to activate the piano pedals. None of them are mainstream/mass-produced; instead, they have been designed by relatively small teams, often for research purposes at different Colleges. The University of Victoria, the University of Heidelberg, as well as Resonate, a small company, are some of the few places that have designed and built a paraplegic piano assistance device. All of them were designed a bit differently, especially in regards to controls and how to smoothly activate the pedals. It's a bit hard to see how exactly each system was designed. However, all of them seem to have the core design of activating the pedals through the use of actuators. The key difference between each design is how they choose to activate the pedals. The University of Heidelberg has come up with 2 separate ways to activate the piano pedals. The first way is using Head movements, which is called the Bernd Schwankl Switch three tilt switches. Turning left activates the left pedal, turning right activates both pedals, and nodding activates the right pedal. The system can be seen in the two pictures below.




(Figures sourced from Steingraeber & Söhne)

The second method that the University of Heidelberg designed is based on chewing. A teeth guard is inserted into the mouth where the user can chew on it. This will activate the actuators at different levels of pressure on the pedals depending on the amount of bite force. A picture of the device can be seen below.

(Figure sourced from Steingraeber & Söhne)

The University of Victoria designed a similar system to the University of Heidelberg's first design through Canassist. Their design is also head-activated and uses a headband to detect the user's movements. This is done through a wireless sensor which measures the changes in its own position. These changes will promptly be communicated to the piano pedal device below to activate the wanted pedals for the user's desired duration.

Resonate, a private company that decided to build a paraplegic piano assistance device, used a similar method to the University of Heidelberg's second design. Resonate uses a mouth splinter to activate the foot pedals. The system is designed very simply - when the controller is bit on, it will activate the pedal. Resonate’s design is focused on simplicity and portability, although it's a bit hard to tell how exactly the design was made, as they weren't very specific about it’s design. It seems like their system can only activate one piano pedal. A picture of their system can be seen below.

(Picture sourced from Resonate Adaptive)

Project Function

Overall Functionality

The overall function of the project is to provide a person without use of their legs the ability to play the foot pedals of a Piano. The solution will be intuitive, comfortable to the player and have an easy setup process.

User input Functionality

The user will command the pedal to be pressed by using a lightweight and low profile 'bite sensor', where the pressure on the device is correlated to the intended pressure on the piano pedal. This signal communicates with a device near the foot pedal. The device then interprets the command and controls an actuator to move the piano pedal.

Actuator Functionality

The actuator must function to replicate a typical foot press and so should have the required force, speed and accuracy that is expected. The actuator will be low profile and have a small footprint so that it does not interfere with wheelchair accessibility.

Control Unit Functionality

The control unit will process the commands from the user and send the required drive signals to the actuator. The control unit will have a display that tells the user the operation mode and have a selector knob for mode selection. The control unit will be input sensor agnostic so that multiple methods of user commands may be used. The control unit will also have power handling capability through USB-C with an integrated battery system for mobile operation.

PROJECT OBJECTIVES AND GOALS

Overall Goals

- Basic:
  - A user with no use of their legs should be able to operate a single piano pedal (the sustainer pedal) in an on and off fashion while playing the keyboard.
    - The user will press a button and the device will control an actuator to apply pressure to the piano pedal.
  - The device's operation will be intuitive.
    - A simple UI for the calibration app, combined with minimal components and quick response times from the system will accomplish this goal.
  - The solution will have a low latency between a user's request and the actuation of the pedal.
    - Sufficient processor clock rates, wireless-communication response times, and motor movement speed will accomplish this goal.
  - The setup process will allow for no permanent modifications to the existing piano.
    - The housing for the finished product will be simple to mount and dismount from most traditional pianos on the market.

- Advanced:
  - A user with no use of their legs should be able to operate three piano pedals, each with varying amounts of force depending on the user's control input.
    - A mouthpiece with 3 resistive pressure sensors for the user to press will accomplish this goal by allowing the user to activate all three pedals independently from one another.
  - The pedal actuator(s) will operate quietly, generally quieter than the piano itself.
    - If necessary, this will be implemented by selecting a noise-insulated material to house the motors in, as long as size and weight constraints stay met.
  - The device will calibrate to the user's specific input pressure(s) using an interface operated through a smartphone.
    - This will be implemented by developing an app interface that can prompt the user to individually press each sensor both gently and forcefully to set a range of pressures and correlate it to each pedal's range from "un-pressed" to "pressed".

- Stretch:
  - A sensor will be implemented that actuates the pedals through electrode-stimulation, without the use of physical force from the user.
    - This goal can be accomplished by having 3 electrodes that can sense when the user activates an attached muscle, and for how long it is activated, to activate the pedal respective to the electrode.

- We design our own motor driver board.
    - An H-bridge circuit will be developed and implemented for greater force/speed control for pedal actuation.
- An external haptic driver based on pedal position will be implemented for user feedback so they can feel the applied force more intuitively.
    - A haptic driver will be controlled based on a force feedback on the pedal.The user will feel the haptic response to know how much pressure is applied.
- An alternative input system will be available for the user that operates using three tubes that the user blows into to activate the pedals, in lieu of the bite/tongue activated input system.
    - The user will blow into three different tubes at different times, this creates a pressure differential that would be sensed with a pressure sensor and the value processed by a microcontroller to communicate the appropriate control signals.

Engineering Requirements

Subsystem Engineering Specifications:

- Motor Subsystem:
    - Contains motors that move the piano pedals based on user input.
    - Converts electrical control signals into mechanical motion.
- Control Subsystem:
    - Central microcontroller that interprets user inputs.
    - Manages control, feedback, and communication.
- Power Subsystem:
    - Provides regulated voltage to the system from a rechargeable power source.
    - Designed for at least 1 hour of continuous operation.
- User Input Subsystem:
    - Includes switches, dials (potentiometers), and buttons.
    - Allows the user to control pedal movement precisely and comfortably.
- Safety & Feedback Subsystem:
    - Monitors for abnormal operation or low pressure from sensors.
    - Includes emergency stop capabilities.
    - Communication Subsystem.
    - Provides Bluetooth connectivity for wireless setup or remote control.

Specification Table	
Motor System	
Motor Response Time	500-700 Milliseconds
Maximum Power Consumption	≤ 20 Watts
User Input (Button/Dial)	
Press Detection Threshold	5-7 Newtons
Button Recognition Time	≤ 500 Miliseconds
Control Unit	
Response Time	< 1 second
Voltage Input	3.3-5 Volts
Maximum Current Draw	< 500 MiliAmps
System Overall	
Device Weight	5-10 Kilograms
Battery Runtime	≤ 1 Hour
Communication Range	≥ 4 meters
Total Delay	≤ 1Second
Response Time	≤2 Second
Acurracy	85-90%
System Setup Time	≤ 2 Minutes

Estimated Project Cost

Bill of Materials				Budget
Component	**Quantity**	**Unit Price**	**Total**	
Battery Holder	1	$6.99	$6.99	$10
ESP32 Dev Board	1	$20	$15	$30
Motors	3	$17	$51	$20.00
Push Buttons	3	$0.30	$0.90	$6.00
Dials	3	$0.50	$1.50	$10
Sensors	1	$60	$60	$40
Battery Pack	1	$7	$7	$15
Voltage Regulator	2	$0.28	$1	$2
Enclosure Box	1	$25	$25	$40
Screws/Mounting Hardware	20	$0.50	$10.00	$30
Jumper Wires, Headers	20	$1.00	$20.00	$15
PCB	2	$50	$100	$100
			$291.16	$308

Related Engineering Standards

USB type C

-https://usb.org/document-library/usb-type-cr-cable-and-connector-specification-release-24

USB Power Delivery

-https://usb.org/document-library/usb-type-cr-cable-and-connector-specification-release-24

Bluetooth

- https://www.bluetooth.com/specifications/specs/

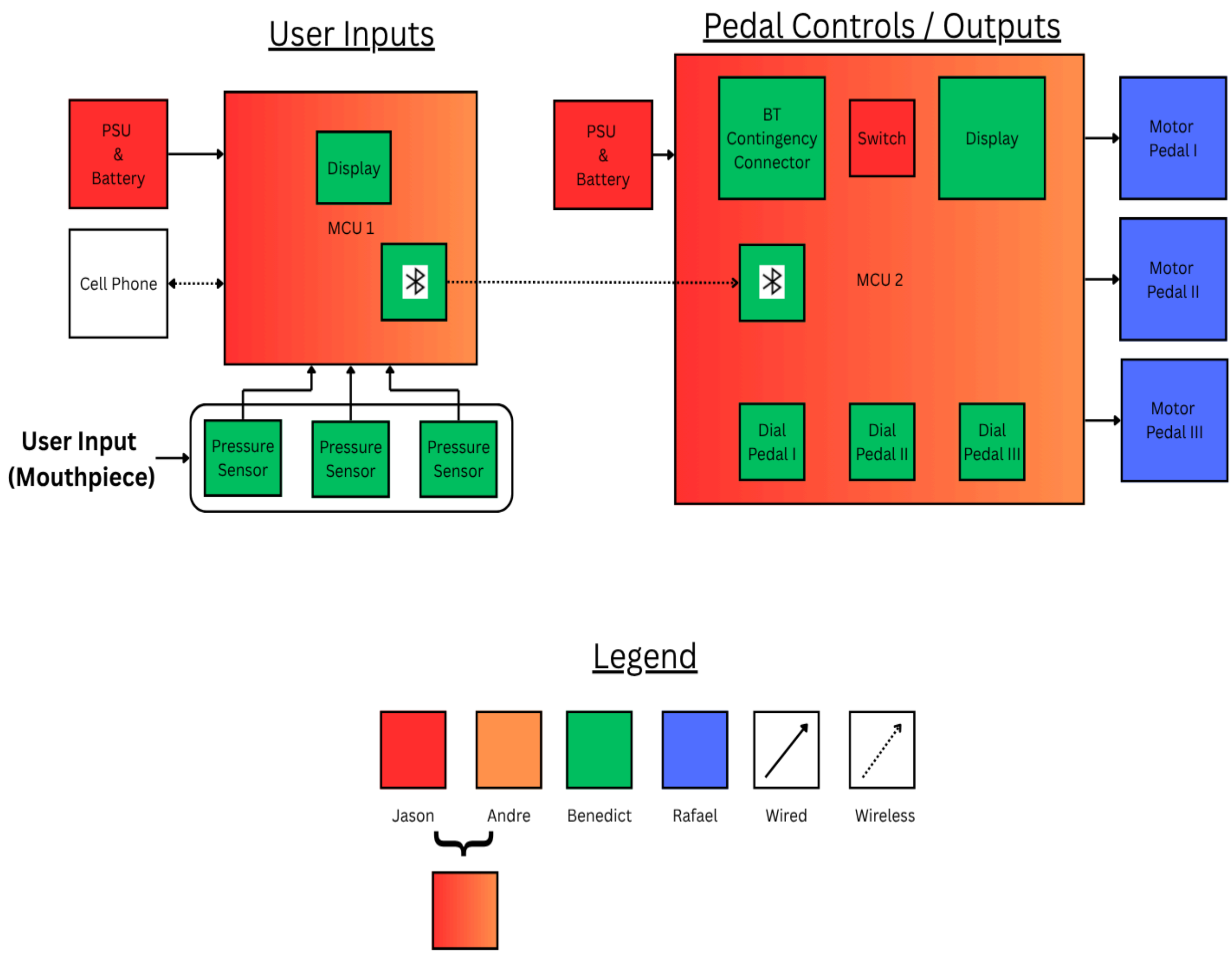
WIFI

- https://ieeexplore.ieee.org/browse/standards/get-program/page/series?id=68

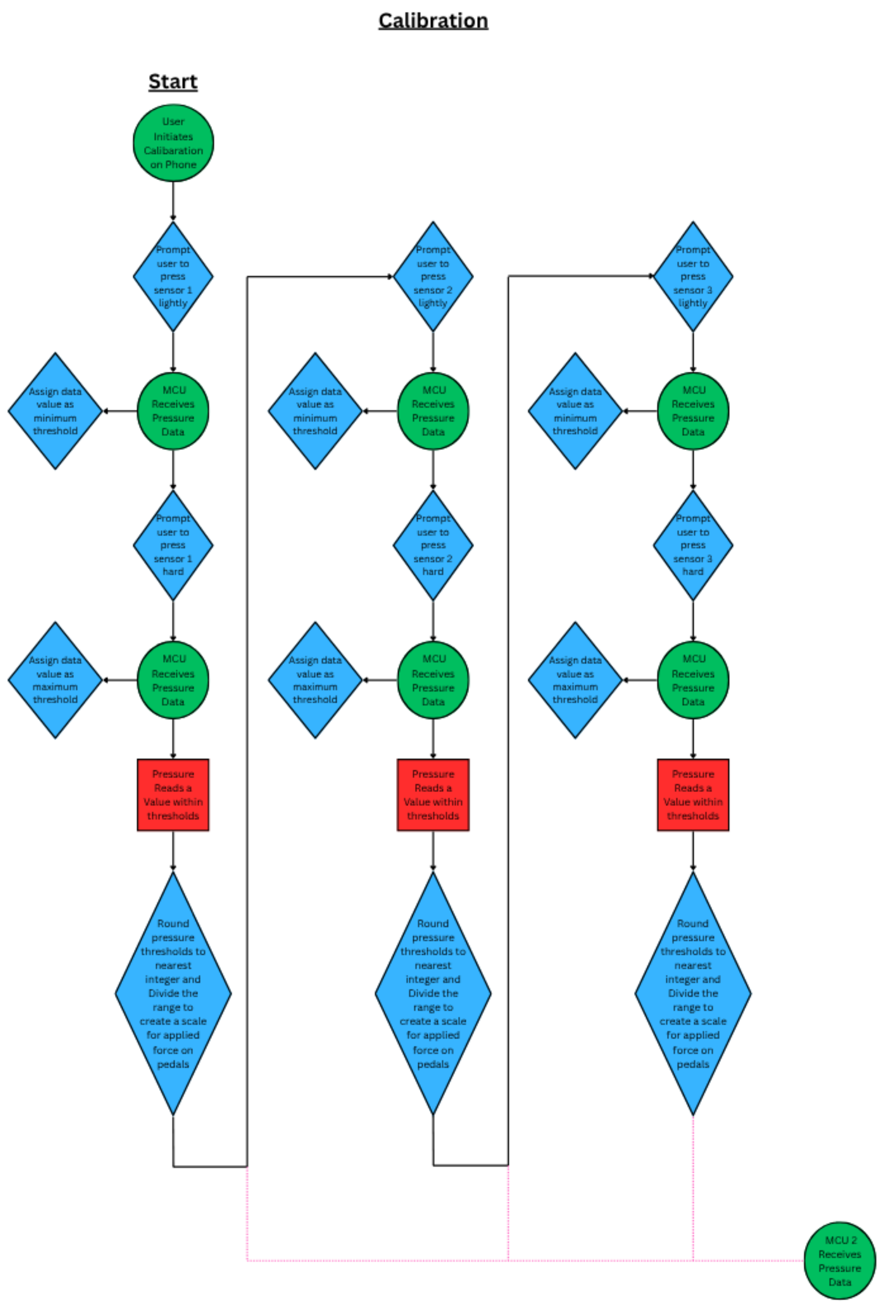
I2C

-https://www.i2c-bus.org/specification/

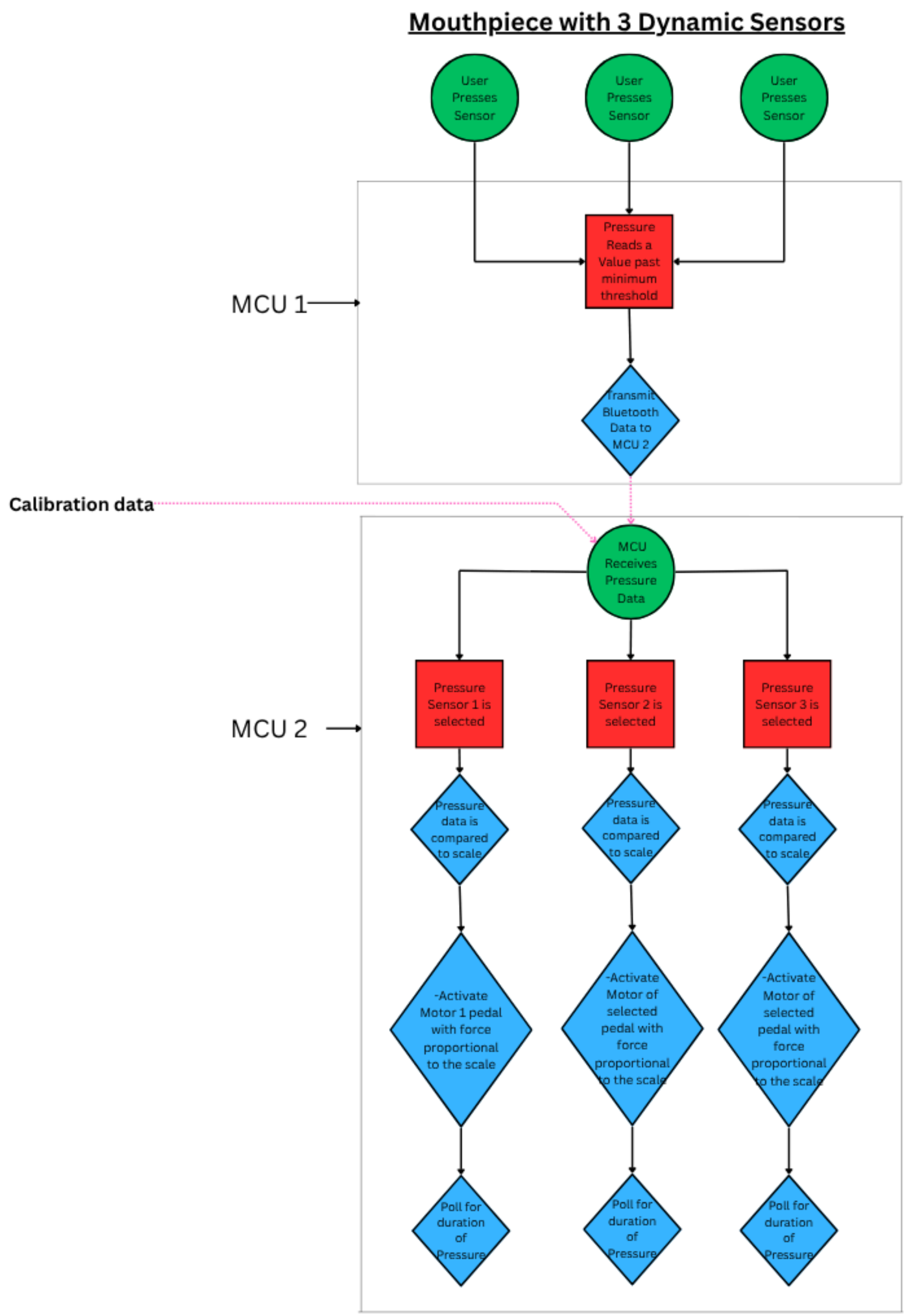
Hardware Connection Diagram



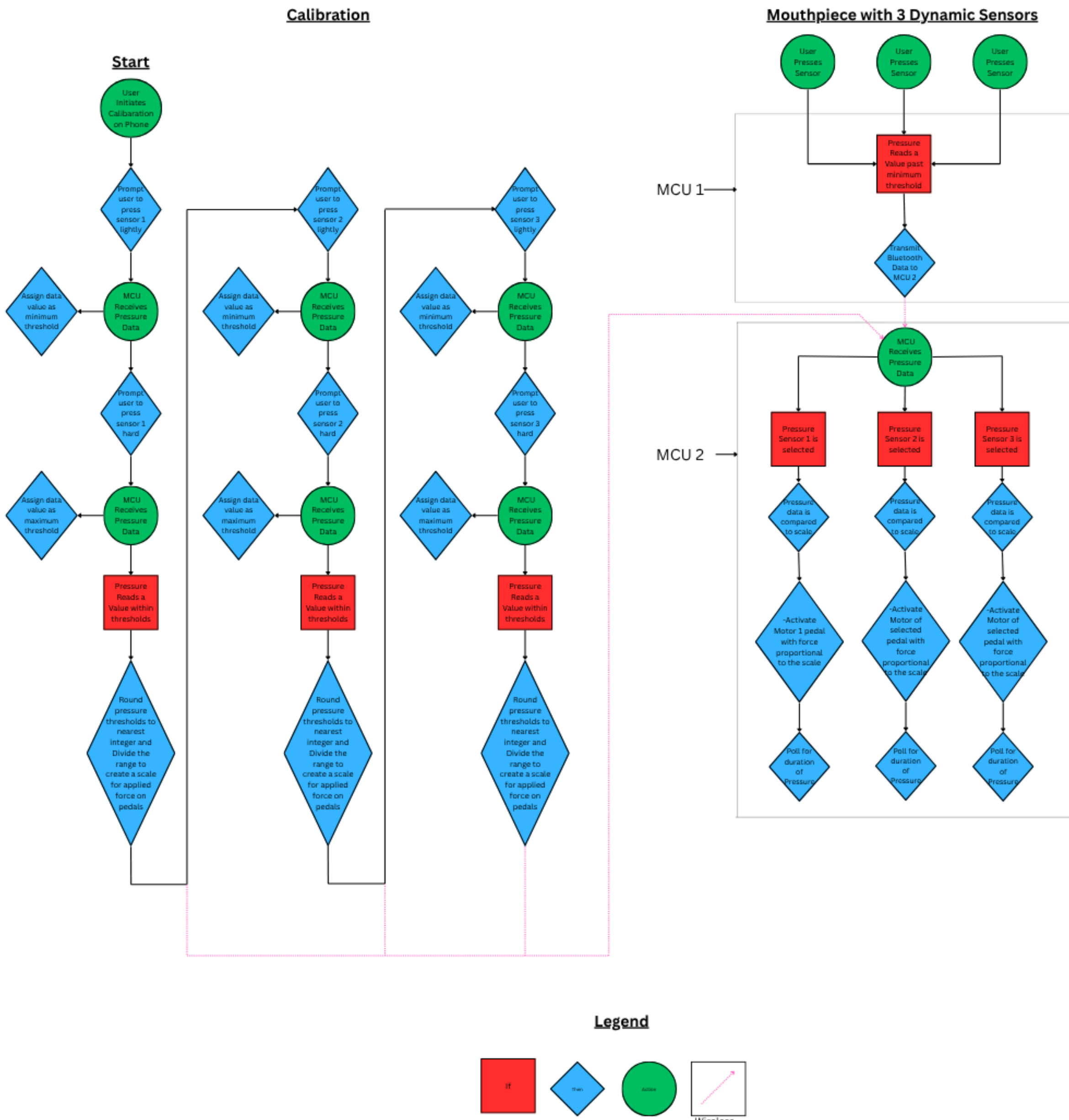
Software Pseudocode Diagram



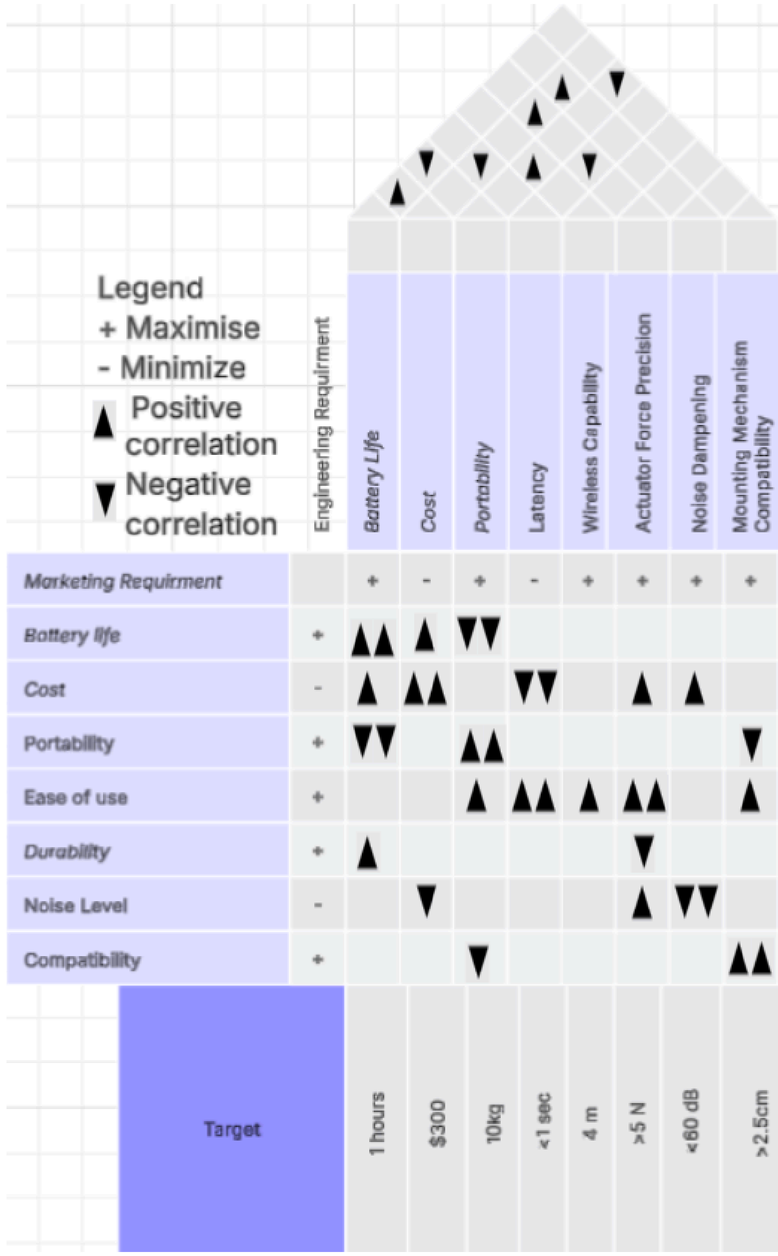
Software Pseudocode Diagram (Contd.)



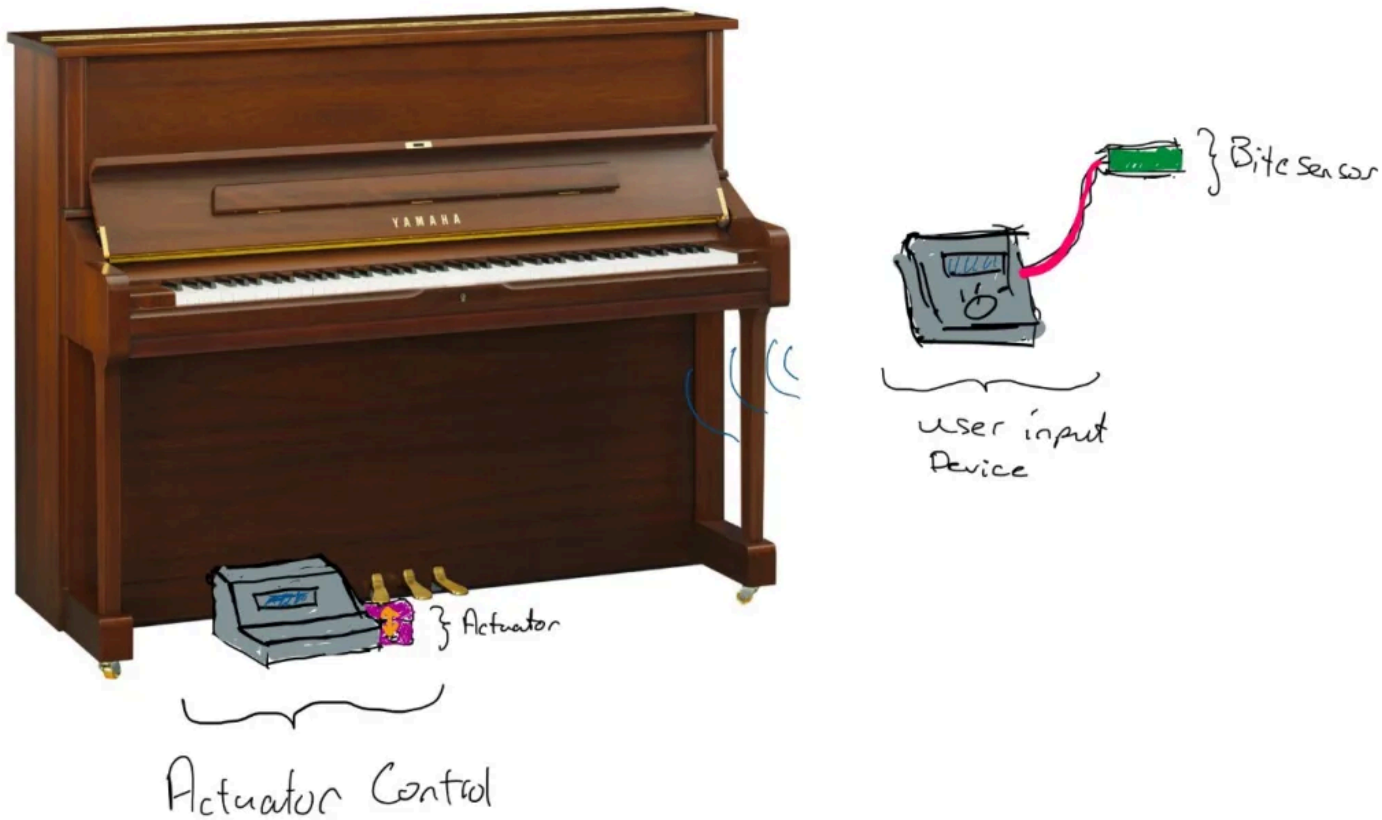
Software Pseudocode Diagram (Contd.)



House of Quality



Sketch of Design



Initial milestones

We are using an app called TimeTree to track our tasks and milestones. A picture of some of the scheduling we have made so far is provided below:

WBS NUMBER	TASK TITLE	TASK OWNER	START DATE	DUE DATE	DURATION	PCT OF TASK COMPLETE
1	**Project Initiation**					
1.1	Supervisor Assignment	Group	6/2/25	6/4/25	2	66%
1.2	Manager Assignment	Group	6/2/25	6/2/25	0	100%
1.3	Individual System Assignments	Jason	6/2/25	6/2/25	0	100%
2	**Project Definition and Planning**					
2.1	Description of Features	Andre	6/2/25	6/5/25	4	50%
2.2	Goals & Objectives	Andre	6/2/25	6/5/25	4	50%
2.3	Budget	Rafael	6/2/25	6/5/25	4	50%
2.4	7 key engineering specs	Rafael	6/2/25	6/5/25	4	50%
2.5	Hardware Constraints	Rafael	6/2/25	6/5/25	4	50%
2.6	House of Quality	Rafael & Benedict	6/2/25	6/5/25	4	50%
2.7	Motivation Background	Benedict	6/2/25	6/5/25	4	50%
2.8	Existing Product Research	Benedict	6/2/25	6/5/25	4	50%
2.9	Hardware Block Diagram	Jason	6/2/25	6/5/25	4	50%
2.1	Software Block Diagram	Jason	6/2/25	6/5/25	4	50%
2.11	D&C Editing and Revision **(DUE ON CANVAS)**	Jason	6/2/25	6/5/25	4	50%
3	**Research and Part Selection**					
3.1	Tentative parts selection (Pressure Sensors)	Andre	6/2/25	6/12/25	4	0%
3.2	Tentative parts selection (Motors/Actuators)	Rafael	6/2/25	6/12/25	4	0%
3.1	Tentative parts selection (Mouthguard/Materials)	Benedict	6/2/25	6/12/25	4	0%
3.4	Tentative parts selection (PSU and Regulation)	Jason	6/2/25	6/12/25	4	0%
3.1	Prototype parts selection	Group	6/2/25	6/12/25	4	0%
3.1	Midterm Report **(DUE ON CANVAS)**	Group	6/2/25	7/7/25	4	0%

PHASE ONE			PHASE TWO		
June 2 - June 6	June 9 - June 13	June 16 - June 20	June 23 - June 27	June 30 - July 4	J
M T W R F	M T W R F	M T W R F	M T W R F	M T W R F	M

Appendix

Appendix A References

CanAssist. "Head-Activated Piano Pedal." *CanAssist*, University of Victoria, www.canassist.ca/EN/main/programs/our-technologies/museum/piano-arts.html. Accessed 25 May 2025.

Steingraeber & Söhne. "Steingraeber Pedal Systems for Wheelchair Users." *Steingraeber*, www.steingraeber.de/en/innovationen/pedal-devices-for-pianists-in-wheelchairs/. Accessed 25 May 2025.

Resonate Adaptive. "Resonate. Make Music Accessible." *Resonate Adaptive*, www.resonateadaptive.com/. Accessed 25 May 2025.