# Smart Walker

**Advisor**
Dr. Amit Nimunkar
**Client**
Dan Kutschera
**The Team**
Nolan BlomWillis (Communicator)
Eva Schiltz (BSAC)
Jacob Parsons (BPAG)
James Waldenberger (BWIG)
Owen Kolnik (Leader)

# Client Description and Problem Statement

## Dan Kutschera

- Physical Therapist
- Acute Stroke clinic in Madison, WI

## Problem Statement

- Our team must design a device that works in conjunction with a standard walker that will measure the speed and distance the patient walks and the pressure applied to the walker.

*Figure 1. Client Dan Kutschera [1]*

# Background

- Currently there is no way to have real-time analysis of a patient's progress with a walker.
- Rehabilitation is shifting more to a data driven approach to rehab.
- Current smart walkers are very expensive.

*Figure 2. Rehab with a Walker [2]*

# Competing Solutions

## Walking Distance Measuring Device

- No pressure readings
- Not a lot of patient information included
- Just a patent currently

## Camino Smart Walker

- Built in boost and brakes
- $2,500
- Not a clinical walker

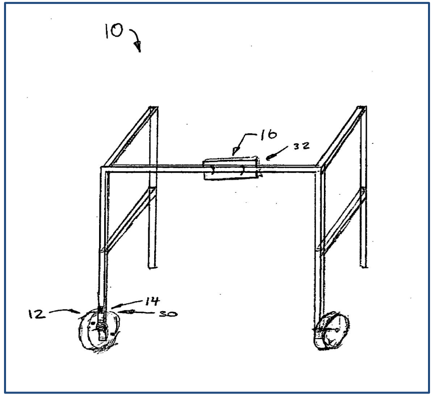


*Figure 3. Walking Distance Measuring Device [3]*

*Figure 4. Camino Smart Walker [4]*

# Design Specifications

- Device must last 5 years without maintenance needed.
- Device will be used for a maximum of 10 patients a day and 5 trials per patient.
- It must run trials up to 100 meters in length.
- Must output measurements in pounds and miles per hour
- Components must be accurate within 5% of measured value.
- Must support the weight of the user (max of 140kg).

# Accelerometer Review

- Used the ADXL345 accelerometer that would pick up acceleration values in the x, y, and z planes
- Varying sensitivities:
  - Higher sensitivities lead to it being more susceptible to error due to gravity
  - Lower sensitivities lead to a lack of deceleration readings
- A balance between the higher and lower sensitivities was not found: constant drift issues

| Sensitivity | Average Velocity (m/s) | Standard Deviation (m/s) |
|---|---|---|
| +/- 2 g | 0.097 | 0.11 |
| +/- 4 g | 0.037 | 0.006 |
| +/- 8 g | 0.053 | 0.046 |
| +/- 16 g | 0 | 0 |

*Table 1. The average velocities measured by the accelerometer at varying sensitivities whilst still*

# Speed Sensor Alternatives

**MPU 6050 Accelerometer**

- 3 axis accelerometer with 3 axis gyroscope
- **Pros**
  - Integrated tech to avoid effects from gravity
  - Have source code
- **Cons**
  - Potential drift issues

**TO-92 Hall Effect**

- Proximity based detection of magnets
- **Pros**
  - Very small, easily integratable
  - Prior group's tech
- **Cons**
  - Presence of other magnetic fields
  - Potential accuracy issues

**TCRT5000 IR Sensor**

- Use of IR transmitter and receiver that detects changes in reflections
- Light based rotary encoder
- **Pros**
  - Simple to set up
  - Very precise and accurate
- **Cons**
  - Potential sources of error due to ambient lighting

# Power

- **Battery**
    - 12.6V lithium-ion battery with 24mAh of charge
    - Comes with protection circuitry, charging cable, and charging block
- **Voltage Regulation**
    - We weren’t able to find a breakout board containing the three different voltage outputs that are needed
    - Individual 9V, 5V, and 3.3V step-down regulators
- **Fabrication**
    - Regulators will receive power directly from the battery, and connect in parallel to power the circuit
    - Everything will be located in the electrical housing box on the front of the walker


*Figure 5. Lithium ion rechargeable battery pack for use in the Smart Walker [5]*

# Power Testing

- **Charge length test**
  - Run code to monitor and store time data until the walker shuts off
  - Last recorded time = Charge length for the Smart Walker
  - Multiple trials
- **Charging speed test**
  - Record time to go from fully depleted to fully charged battery while plugged in to the outlet
  - Multiple trials
- **Heat of components test**
  - Measure temperature on the surface of the step-down regulators until it stays the same between measurements
  - Gives upper-bound for the temperature of the regulating components
  - Multiple trials for 9V, 5V, and 3.3V regulators
- **Possible other tests**

# Load Cells - Previous Work

- **Successes**
  - High accuracy (±1% of real value)
  - Decent power efficiency (~16mA)
- **Problems**
  - Noisy signal, so the average between multiple values was taken
  - Not calibrated for final setup
  - Using breadboard instead of PCB board
  - Committing to a lead polarity means we could double the gain in the circuit for a more accurate reading → Replace/alter level shifter

# Load Cells

- **Moving forwards**
  - Implement regulated voltage into load cell circuit
  - Create PCB for all circuit components of the Smart Walker
  - Integrate load cells into load cell holders on each leg of the walker
  - Feed wires through the legs of the walker to their respective destinations
  - Re-calibrate with all changes made

# Load Cell Housing - Previous Work

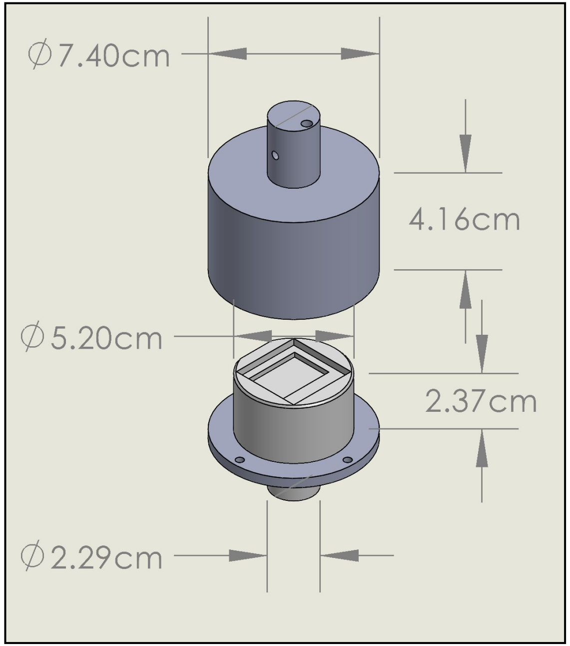


*Figure 6. Dimensioned SolidWorks assembly of housing chambers for the load cells*

*Figure 7. 3D printed loading cell housing prototype*

# Load Cell Housing

**CAD Model**

- ABS minimum flexural yield strength of 60.6 MPa means the factor of safety is 8 [6].
- The reduction of strength through 3D printing can be offset by using a high infill (80%).

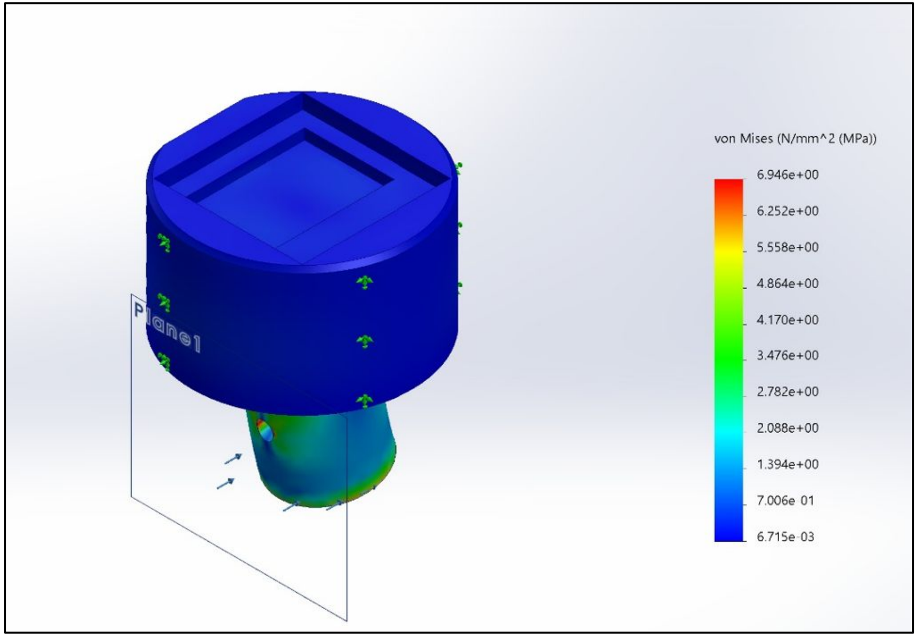


*Figure 8. Results from SolidWorks simulation of the load cell holder*

# Load Cell Housing With Walker

*Figure 9. Current image of prototype featuring integration of load cell housing with walker*

# Load Cell Testing - Weight Measurement

- **Method**
  - Measure weight of wooden board
  - Rest board across walker rails
  - Record weight registered by load cells
  - Progressively add plates of known weight onto the wooden board, recording registered weight between each plate
  - Compare actual weight to recorded weight
- **PDS Criteria**
  - Must measure up to 140 kg of weight
  - Must be accurate within +/- 5% of applied weight

# Load Cell Testing - Functionality

- **Protocol**
  - Group members will take turns walking 10 meters each over a period of 30 minutes.
  - The height of the walker will be measured and adjusted between trials
  - The weight of the walker will be measured using a scale.
  - Group members will make qualitative observations on functionality of the device: stability, comfort, ease of movement, etc.
- **PDS Criteria**
  - Must not impede function of the walker
  - Walker must weigh between 4.5 and 9 kgs
  - Walker must be adjustable and have a height of between 0.8 and 1.1 m

# Electrical Housing- CAD Design

**Purpose**

- Hold Power Supply and Sensor Circuitry.

**Design Criteria**

- Must not interfere with patient walking.
- Must protect circuitry.
- Must allow wires to exit housing.
- Must securely attach to walker.
- Must allow access to internal wiring.
- Must allow for walker folding.

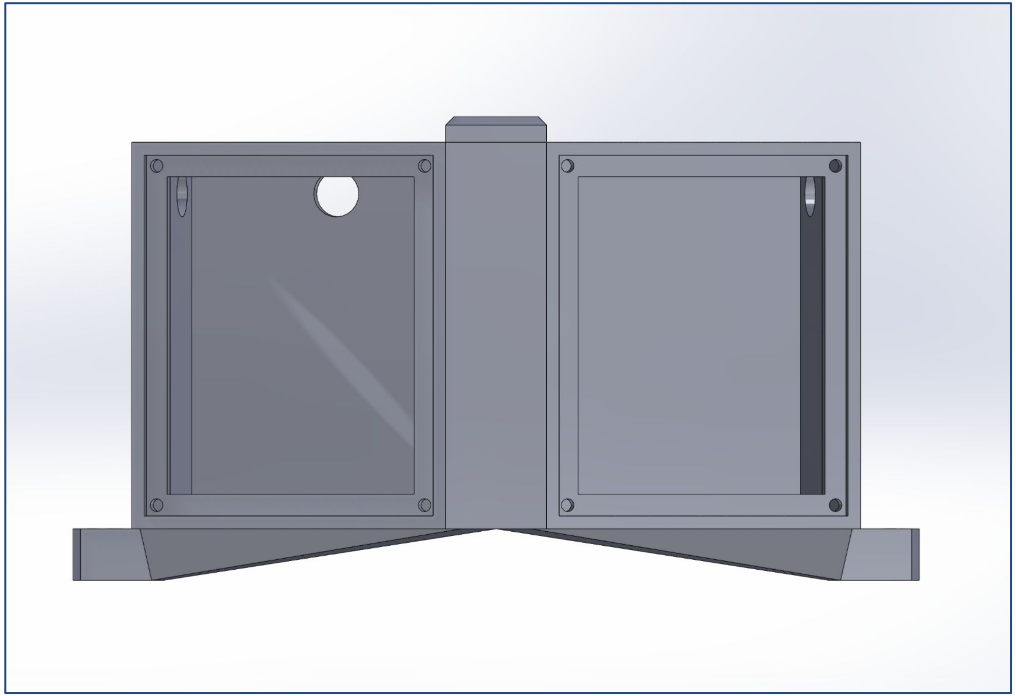

*Figure 10. Electrical Housing CAD Design*

# Electrical Housing - Design Dimension

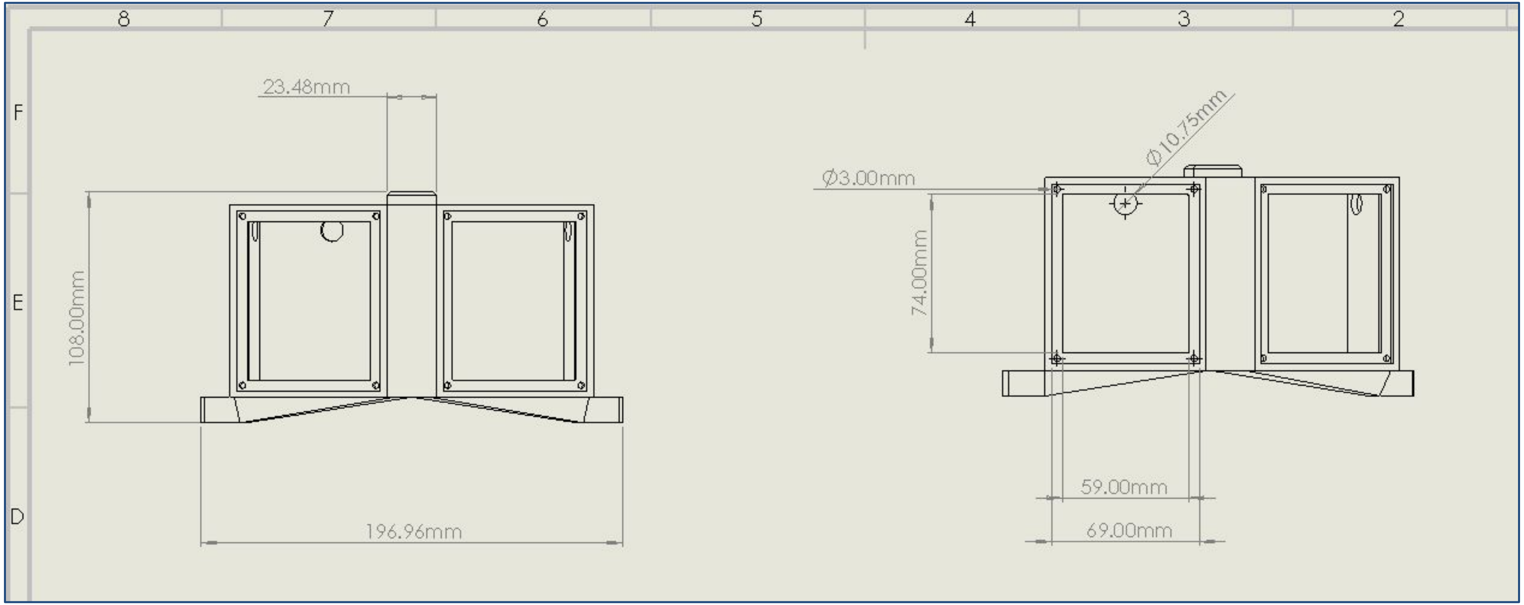


*Figure 11. Electrical Housing Dimensions.*

# Electrical Housing - FE Analysis

**<u>DISCLAIMER:</u>** Material is 3D printed anisotropic Polypropylene, HOWEVER material properties were sourced from Polypropylene separator testing (transversely Isotropic but not laser cured) [7].

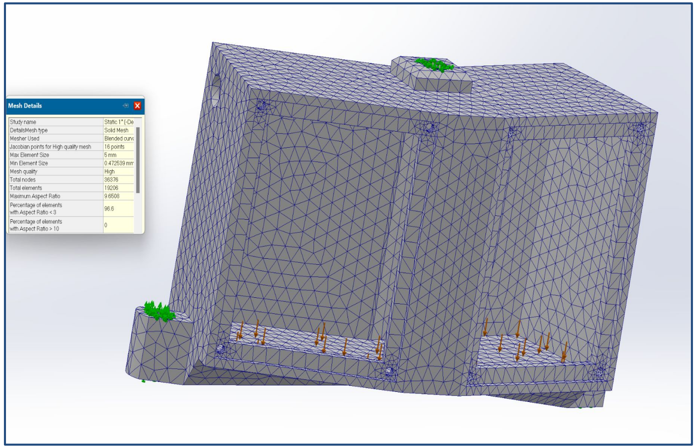


*Figure 12. FEM Mesh*

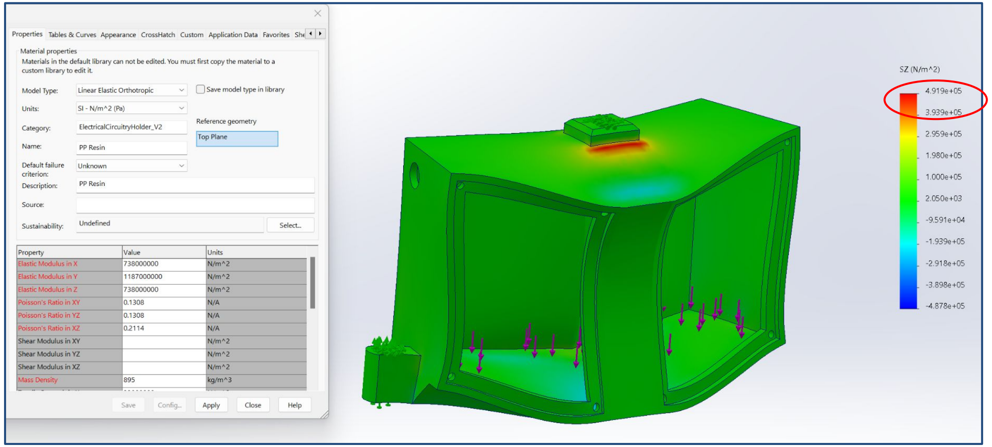


*Figure 13. FEM Z Normal Stress*

Applied Load: (5x) Battery Weight & Housing Weight

Weakest Direction Yield Stress (Z): 17.55 MPa [8]

Distortion Energy Safety Factor (Z-Normal): ~ 35.7

# Final Fabrication - Electrical Housing Assembly

**Components**

- Pipe Clamps (3x)
- Attachment Bolts and Nuts (3x)
- Heat Set Threaded Inserts and associated Screws (8x)
- Removable Doors (2x)
- Main Electrical Housing Body
- Velcro Strips
- Washers (3x)

**Material**

- Formlabs Tough 1500 Resin

*Figure 14. Electrical Housing with all Components*

# Final Fabrication - Hardware Block Diagram

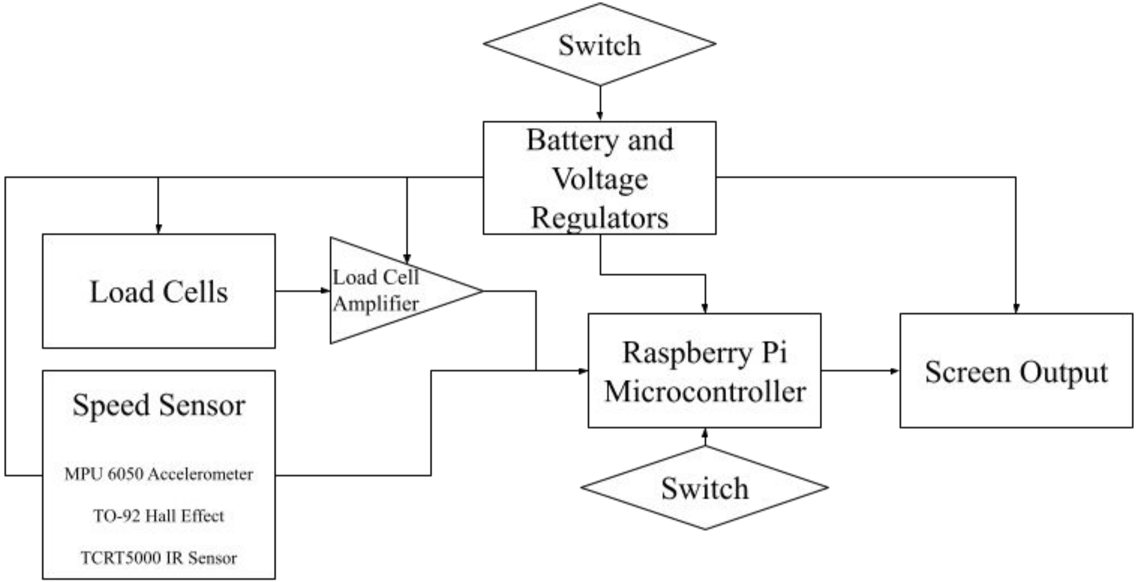


*Figure 15. Hardware Block Diagram*

# Final Fabrication - Software Block Diagram

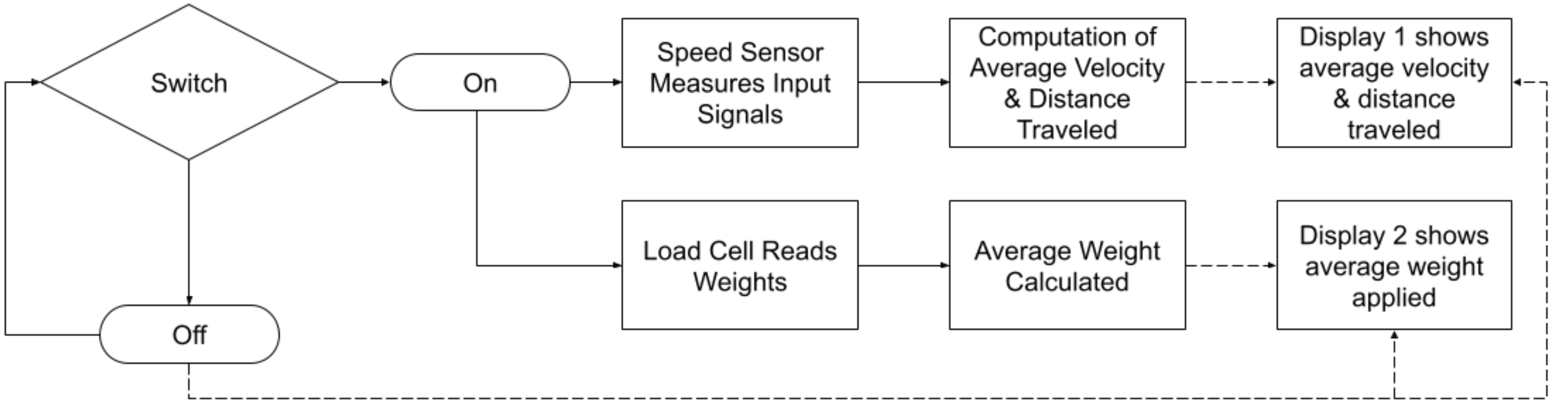


*Figure 16. Software Block Diagram*

# Acknowledgments

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