SMART WALKER

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Client: Mr. Dan Kutschera

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UW BME Design

Problem Statement

- Within the neurorehabilitation process, clinicians or physical therapists often aim to reduce a patient's dependency upon walkers as they regain motor control.
- The client, Mr. Dan Kutschera, a physical therapist at the UW Rehabilitation Hospital, requests a sensorized smart walker that can track in real time a patient's distance traveled, gait speed, and applied pressure distribution on the walker.
- The data can be utilized for motivational purposes and to evaluate improvement and the efficacy of intervention strategies for insurance/medicare reasons.

Motivation and Background

- A number of neurological disorders and injuries (stroke, traumatic brain or spinal cord injury, ALS) can lead to physical impairment[1]
- Patients in physical therapy often use transitional devices(walkers) to practice various daily activities
- No clinically targeted "smart" walker on the market to measure various metrics such as gait speed, pressure, distance.[2]
- A sensorized smart walker would enhance the neurorehabilitation process by providing vital data for progress monitoring of a patient's motor independence.

Figure 1. Camino Smart Walker[2]
Motorized smart walker at $2000 with many unneeded features for clinical use

Design Specifications

- The Smart Walker **should support 136 kg**, be adjustable for varying patient heights, and have **sensors accurate within 5%** and read up to a **speed of 3.0 mph(0.1 mph precision)**
- Pressure sensors should **measure up to 70kg (1 kg precision)**, and the design must be insensitive to sanitizing materials for safe use by multiple patients in a clinic setting.
- The walker used by our client for his patients has **2 wheels and 2 gliders**.
- The design must avoid obstructing the patient's path and should **not add more than 1.81 kg** to the 3.63kg purchased walker.

Figure 2: Walker [3]
Similar model to that found in clients facility

Final Design and Prototype

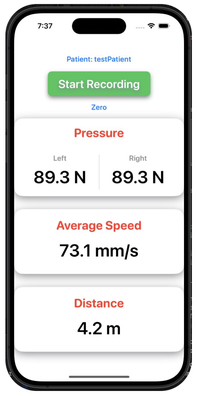


Figure 3. iOS App User Interface, SwiftUI

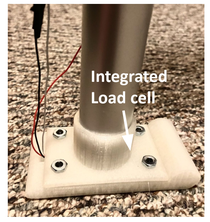


Figure 4. Complete Foot Assembly with integrated load cells

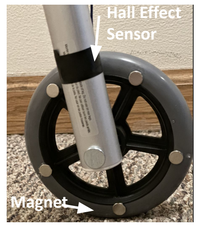


Figure 5. Wheel with equally spaced magnets and hall effect sensor

Figure 6. Full view of walker with integrated sensors and microcontroller

- Magnet/Hall Effect sensor senses equally spaced magnets on wheel to calculate speed
- Load cells in feet of walker used to relay force data
- Force, speed stored in Google Firebase Server, displayed on iOS app in real time

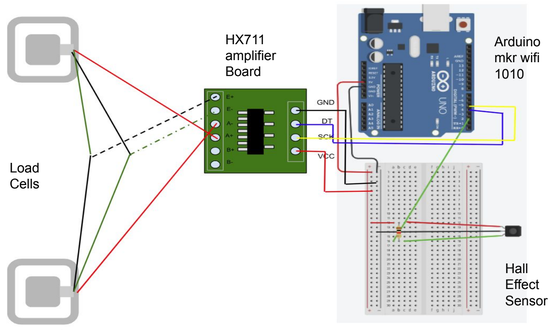


Figure 7. Load Cell and Hall Effect Sensor Circuit, TinkerCad

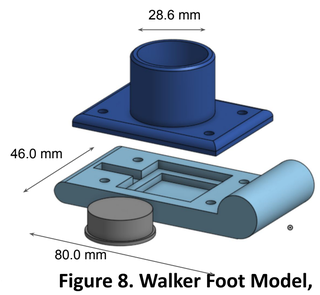


Figure 8. Walker Foot Model, Side View
Figure created in Onshape

Arduino MKR WIFI 1010 Software Flow

Connects to local wifi network, initializes hall effect and load cell sensor input pins

Force, Total Distance Calculated, every 1 second data **sent to firebase server**

$$\text{Force} = \frac{\text{Voltage Signal}}{\text{Calibration Factor}}$$

$$\text{Distance} = N * \frac{\text{Circumference}}{\text{\# of Magnets}}$$

Firebase Server

Data stored in JSON hierarchy

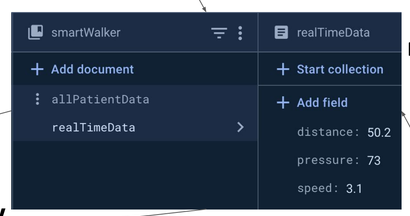


Figure 9. Google Firebase Server View

Upon Stop: Total distance, Average Pressure, Speed stored in Server

iOS Application Flow

User Clicks **Start Recording**, Begins continuously **retrieving data**

Logs, displays total **distance** traveled(m) (current distance - initial distance)

Logs, displays average **speed**(m/s)(total distance / time)

Logs, displays Force(N) values

Testing & Results

- Near real-time values can be sent from walker and saved to Google Firebase & App when connected to WiFi
- 3 trials of varying known weights were applied to walker handles
- Performed a paired t-test
- p(0.05) = 0.4182, scale weights and walker weights not statistically different
- Average error: 7.97%
- $CI_{error}(0.95)$= 8.39%

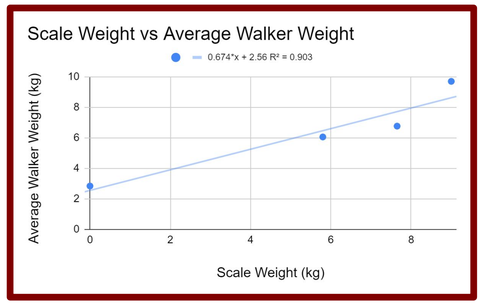
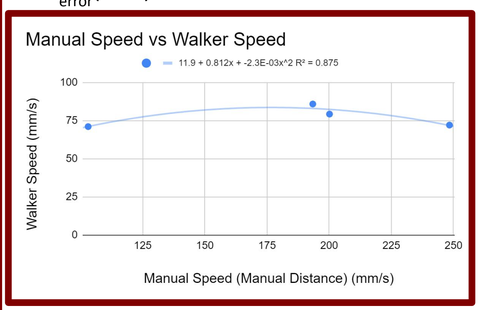


Figure 10 : Scale Weight vs Walker Weight



- Strolled walker along 10ft path
- Min error = 31%
- Paired t-test
- p(0.05) = 0.035, statistically different

Figure 11 (left): Manual Speed vs Walker Speed

Conclusion/Future Work

PDS Criteria: Speed Accuracy, Precision, Range	• Successfully measures **speed to 0.1 m/s** precision and within a **range of 0 to 3 m/s** • **Min error of 31%(>5% target),** significant refinement needed • Speed accuracy needs improvement, potentially by adding stronger magnets, more sensitive hall effect sensor
Pressure Accuracy, Precision, Range	• Successfully measures **up to 70kg weight to 0.1 kg precision.** • **Average error** of 7.97% is **greater than 5%** and not within accuracy tolerance • More tuning/calibration of load cells needed
Walker weight and assembly	• Added weight is **0.23 kg(<1.81 kg target)** • Prototype cost **$283(<$400 budget)** • Can reduce interference by running wiring through walker legs • Implement arduino for sending data and arduino for sensors for >temporal accuracy

References

[1] S. L. James et al., "Global, regional, and national burden of traumatic brain injury and spinal cord injury, 1990–2016: a systematic analysis for the Global Burden of Disease Study 2016," Lancet Neurol., vol. 18, no. 1, pp. 56–87, Jan. 2019.

[2] "Camino : The World's First Smart Walker." Camino Mobility, caminomobility.com/. Accessed 22 Sept. 2023.

[3] Amazon.Com: Drive Medical 10210-1 2-Button Folding Walker with Wheels ... www.amazon.com/Drive-Medical-10210-1-Lightweight-Adjustable/dp/B001HOM4U2. Accessed 7 Dec. 2023.