Finger Extension Assistive Device (FEAD)

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Abstract

- Traumatic brain injuries (TBI) often result in motor impairments, including hand paralysis.
- Tasked with fabricating a device that assists with finger extension.
- Fabricated thread and motor mechanism that pulls index finger into extension position.
- Designed electronic circuit and code that activates a motor in response to a stimulus pressure.

Problem Definition

Motivation

- Annually, 2.5 million individuals sustain a TBI [1].
  - 56% of TBI survivors have motor impairments, which can manifest as increased flexor tone, resulting in a resting clenched fist position [1].
- TBI-related hand paralysis necessitates the fabrication of a device that assists in hand extension.
  - Finger extension strength and stability is needed to grasp and grip objects.
- Existing devices do not provide rehabilitation for finger extension motor function [2].

Background

- The extensor digitorum muscle of the posterior forearm extends the medial four fingers [3].
- Average finger extension angles [3]:
  - Metacarpophalangeal Joint: 45°-90°
  - Proximal Interphalangeal Joint: 10°-20°
  - Distal Interphalangeal Joint: 0°-10°
- 40N of extension force is required to extend low-tone fingers [4].
- TBI often results in spasticity, the uncontrolled tightening of muscles caused by disrupted signals from the brain [5].

Design Criteria

- Extend balled fist (180°) to a flat position (0°) [3].
  - Able-bodied individuals move their fingers through a range of motion of 164° [6].
- Strengthen finger extension motor function overtime.
  - Device must be activated by the client.
  - After 10 weeks of use, client should improve original unassisted extension angle by 12°-19° [7].
- Thread must pull and sustain the weight of a singular finger.
  - Average weight of index finger is 18-22 grams [8].
- Device must be biocompatible, sweat resistant, and easily sanitized.

Final Design

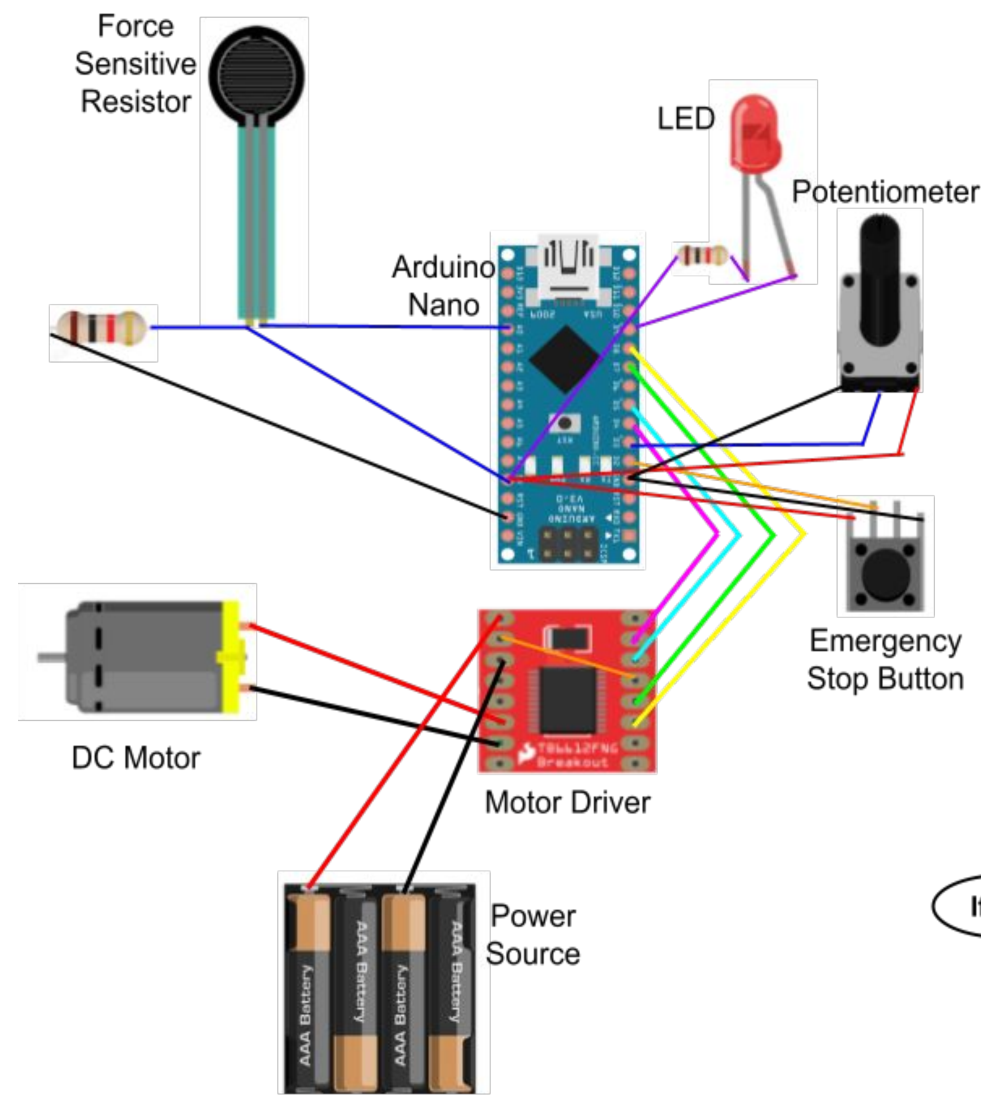

Fig. 1 Electronics schematic. Pressure applied to FSR is processed in Arduino Nano and communicates with motor driver to control DC motor. Potentiometer controls threshold value.

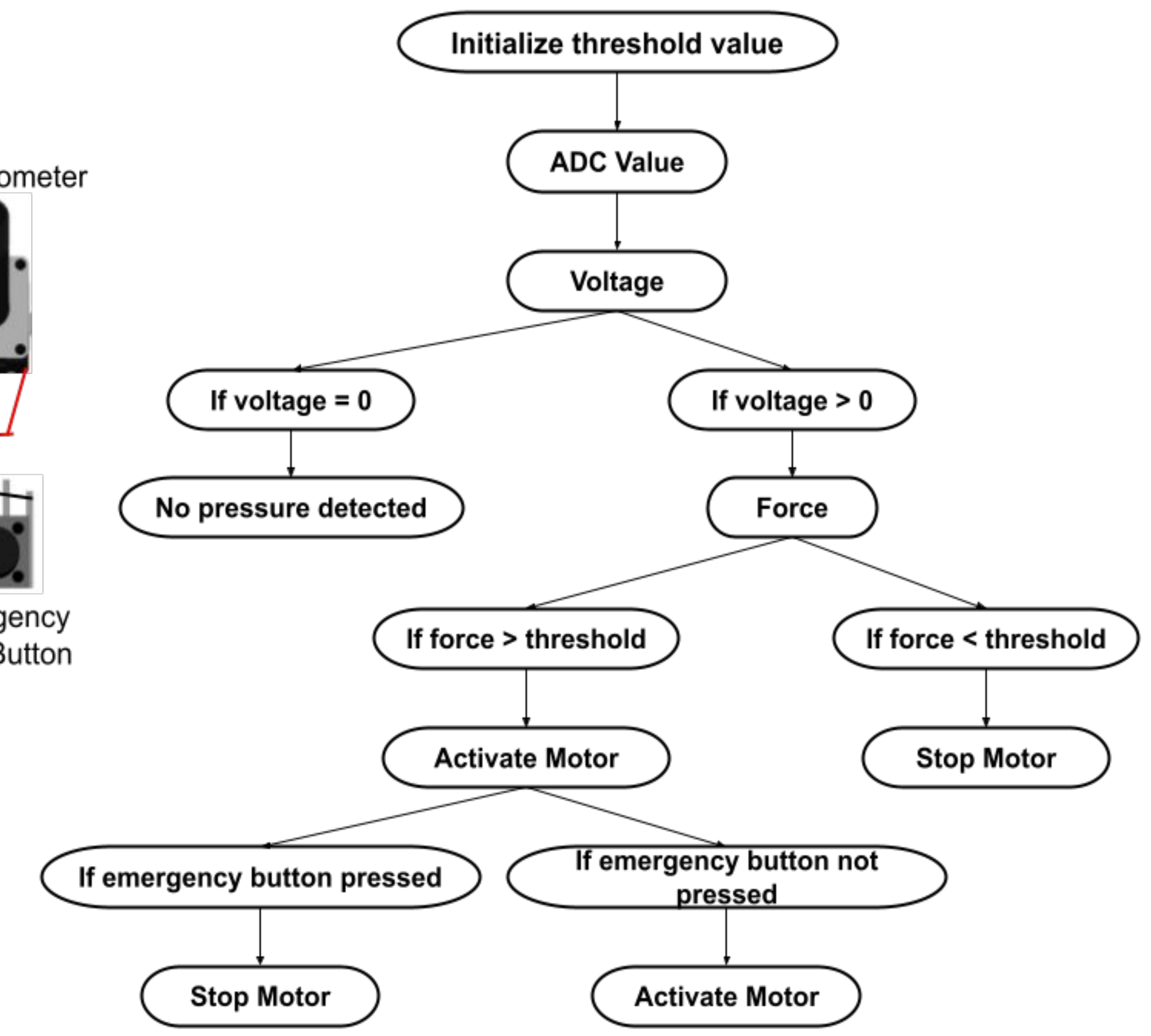

Fig 2. Arduino code loop. Motor is activated if stimulus pressure applied to FSR is greater than the threshold value.

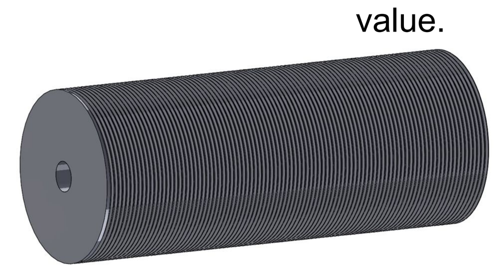

Fig. 3 SolidWorks rendering of 3.4V motor axle. Placed on DC motor, where thread catches.

Fig. 4 SolidWorks rendering of finger braces. Used in duplicates to prevent over extension of the finger.

Fig. 5 SolidWorks rendering of 24V motor axle.

Fig 6. Final design components. Soldered electronics, 3.4V DC motor, and threaded glove.

DC Motor Capacity

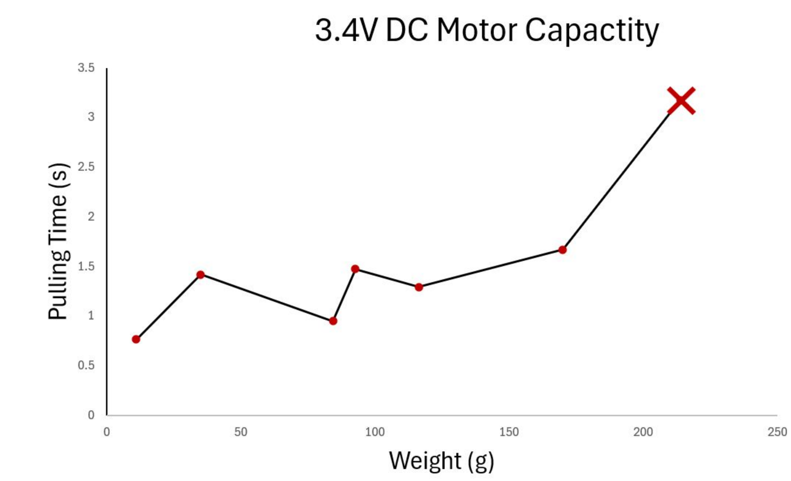

Fig 10. 3.4V Motor Strength Time(sec) vs. Weight (g)

- Determined the capacity of the 3.4V DC motor by measuring the maximum weight the motor can pull in the horizontal direction.
- The 3.4V DC motor was unable to apply enough torque to extend the index finger.
- Applied the vertical and horizontal test to a 24V DC motor as an alternative.
  - Able to pull weight greater than 300g in both directions.
  - 3D printed axle for 24V motor.
    - Length: 6.5 cm
    - Radius: 0.5 cm

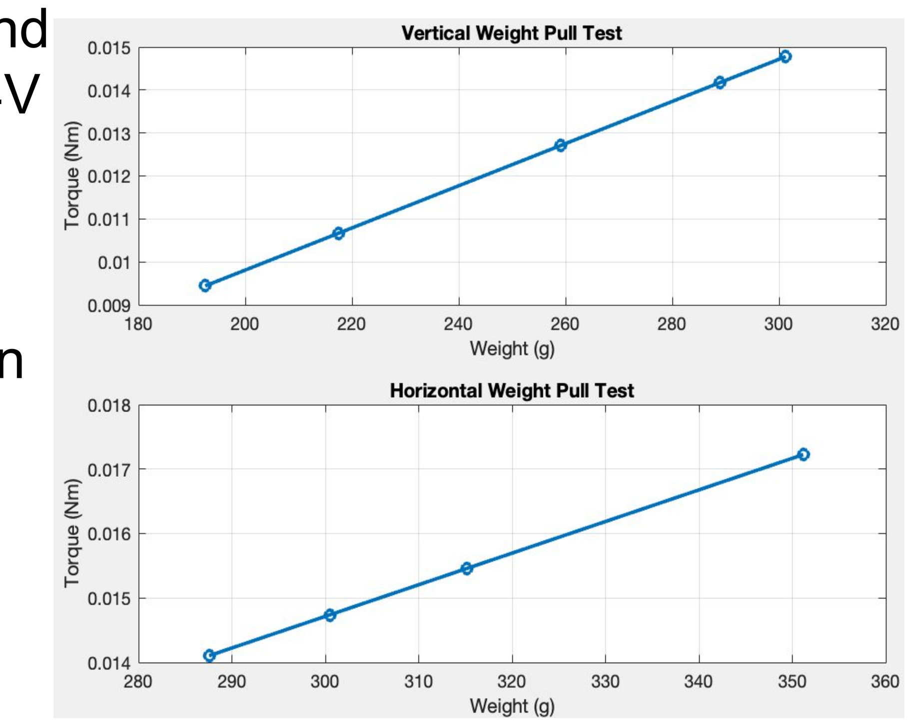

Fig 11. 24V Motor performance during the vertical and horizontal weight pulling tests

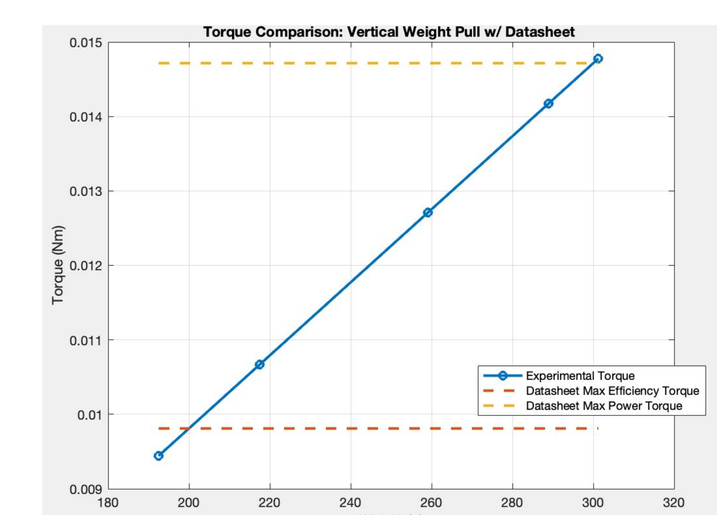

Fig 12. Comparison of Torques from Datasheet to experimental values from Vertical Weight Pull Test

- Constant:
  - g=9.81 m/s^2
- From the 24V motor datasheet:
  - Torque at Max Efficiency: 100 g*cm
  - Torque at Max Power: 150 g*cm

Testing & Results

Sensor Validation

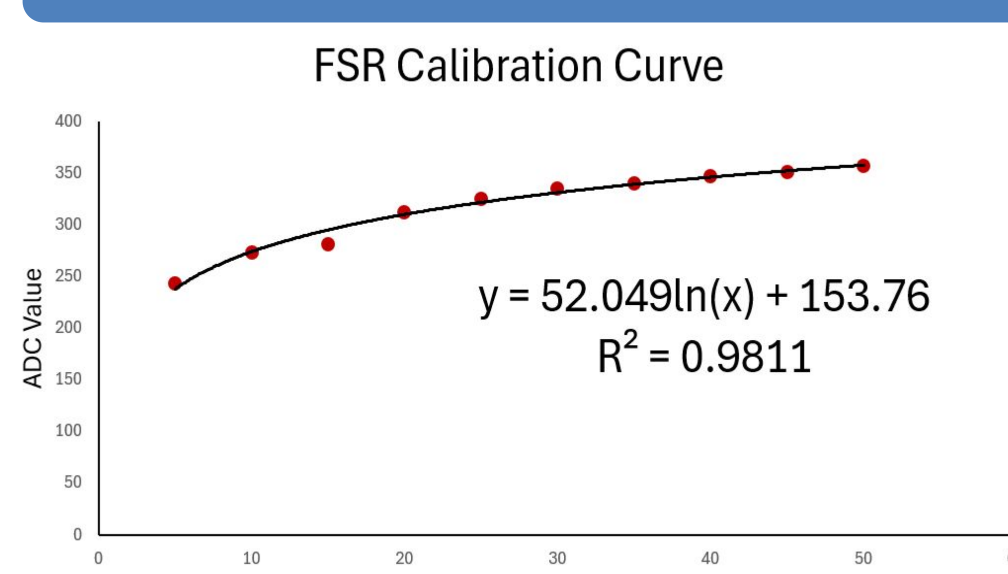

Fig. 7 FSR Calibration Curve

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Force in Newtons: 4.07
Current Threshold: 0.50
Pressure Applied for 1 Seconds
Motor Activated - Pulling Thread
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Fig. 8 Arduino Output

Fig. 9 MTS Machine

- Using MTS machine, compressive loads were applied to FSR and corresponding ADC values were collected.
- Logarithmic FSR calibration curve. Equation applied to Arduino code to calculate applied force.
- Confirmed force calculation in Arduino code by applying known loads to FSR.

Future Work

- Add the 24V DC motor to the electronics and glove design.
- Apply the thread and motor system to all four fingers. Update code to control individual finger extension.
- Develop an app that records and displays force exerted. Used to determine finger extension strength overtime.
- Develop code and mechanism to allow for partial finger extension.

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References

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