Sensor and Servo Enhanced Smart Arm Cast

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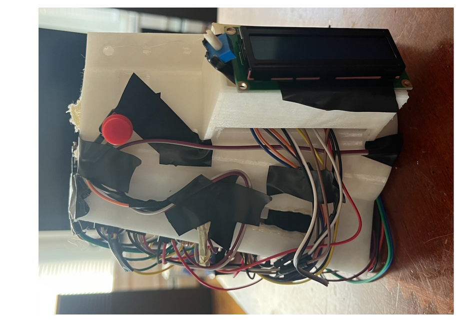


Photograph of assembled Smart Arm Cast with wires exposed

OBJECTIVES

I: Ideate a potential product that serves as a smart wearable device for consumers

II: Design a model with the use of mechanical equipment and engineering principles

III: Develop the model to create a functional prototype of the smart wearable cast

IV: Test, analyze results, redesign, and redevelop the product for improvement

MOTIVATION

- 2.6 million emergency room visits per year due to fractures [1]
- Current casting processes use skin-irritating and non-reusable material
- Cast applications require tedious multi-step methods [2]
- The healthcare industry lacks smart devices accessible to patients
- Sensor-based technology will efficiently and effectively fixate an injured wrist autonomously [3]

Doctor applying short arm cast to a patient

CAST MATERIAL AND DESIGN MODELING

Material & Design Background

- Protective Layer constructed from Thermoplastic Polyurethane (TPU)
- TPU filament was used to 3D print protective cast layer
- Cast Design constructed using SolidWorks
- The design of the cast needed to take into account the size of an elbow and wrist for the respective diameter dimensions of the model

Thermoplastic Polyurethane Material Properties		
Property	Value	Description
Density [g/cc]	1.45	Light-weight, Low density
Hardness [R]	66.3	Durable, Hard
Max Tensile Strength [Mpa]	63.3	Durable; Can withstand high force and pressure
Elastic Modulus [Gpa]	2.58	Relatively low elastic modulus, easily stretches, does not deform
Elongation at Yield [%]	23.8	Amount material can stretch from its original state without breaking
Elongation at Break [%]	26.6	Amount material can stretch till breaking
Flexural Modulus [Gpa]	2.18	Relatively flexible; Low resistance to bending force
Water Absorption [%]	0.24%	Low water absorption

Table 1: TPU Material Properties

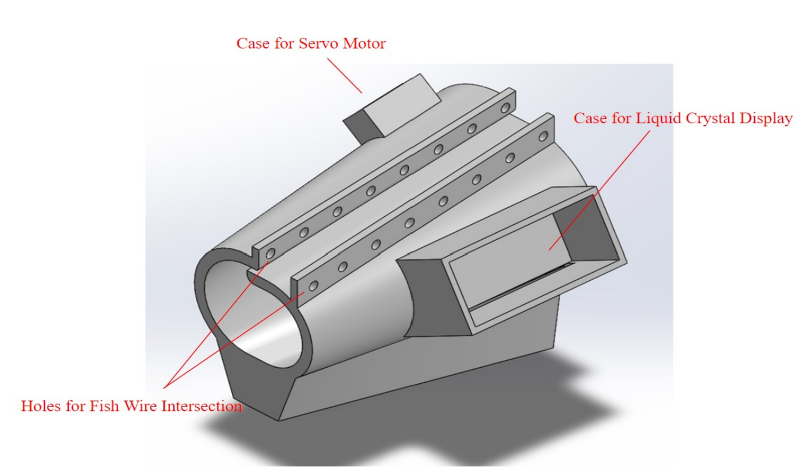


Figure 2: Isometric View of Cast in SolidWorks

Cast Dimensions:

- Wrist diameter: 54mm
- Elbow diameter: 97mm
- Length of the cast: 6 in
- Uniform Thickness: 6 mm
- Lofted Slot Height (Elbow): 45mm
- Lofted Slot Height (Wrist): 30mm
- LCD Case Interior: 32mm
- Servo Motor Case Interior: 18mm

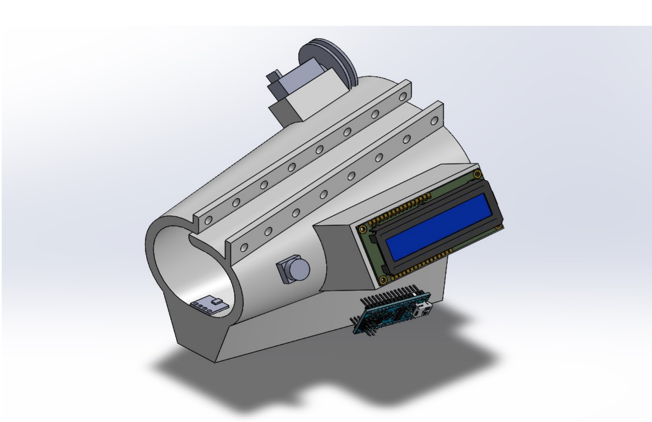


Figure 1: Final CAD cast Assembly in SolidWorks

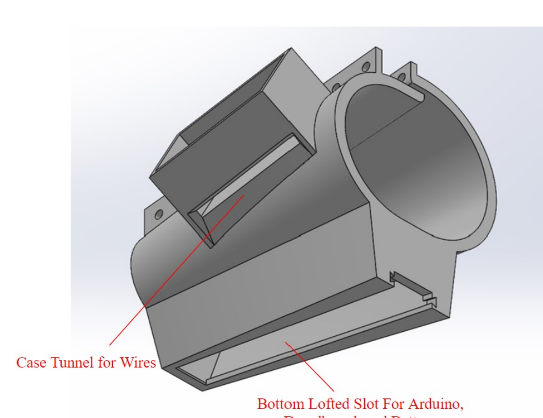


Figure 3: Bottom-Left View of Cast in SolidWorks

CAST SENSORS AND EQUIPMENT

Tower Pro SG92R Servo Motor

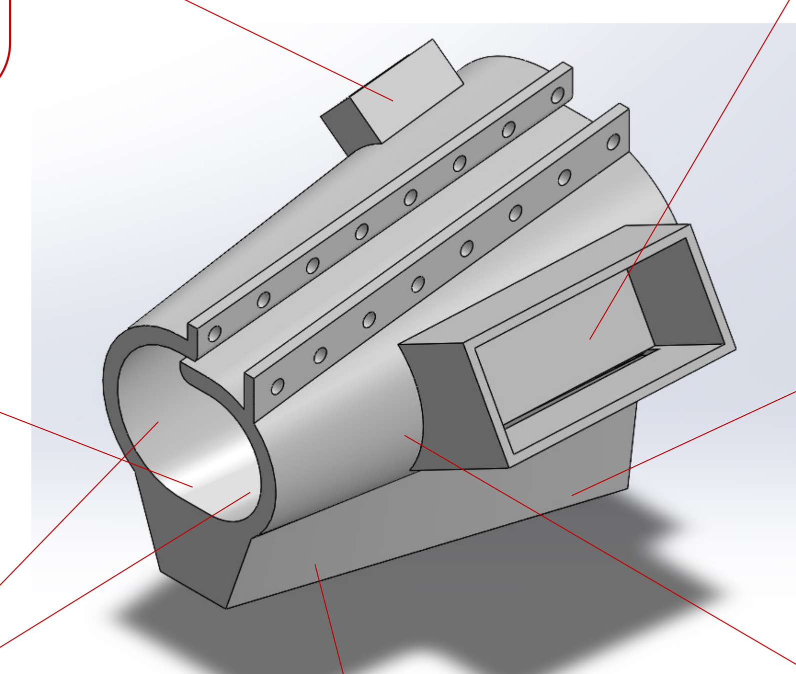
Tightens and loosens cast using nylon wire and a pulley wheel

16x2 Liquid Crystal Display

Displays heart rate and tightening pressure to patient

MAX30102 Pulse Oximeter

Detects heart rate by sending and receiving light waves in the patient's blood vessels



Battery

Supplies 4.5 Volt Power to Wires

(2x) Strain Gauge

Attached at either side of the patient's forearm; Detects the pressure the cast puts onto the patient's arm

Arduino Nano R3

Computer controller calculating pressure and electrical signals to operate motor and pulse oximeter

Switch Push Button

Placed so that the patient can recalibrate the tightness of the cast during the coding

ARDUINO WIRING AND CODING

1. Takes baseline pressure readings from the strain gauges
2. Translates strain gauge value to degree position for servo motor to establish its baseline position
3. Measures the patient's average heart rate at a given time with the pulse oximeter
4. Based on the measured value, the servo motor turns. If the heart rate is:
   - Less than 65 BPM, the servo turns clockwise 5 degrees, tightening the cast
   - More than 110 BPM , the servo turns counterclockwise 5 degrees, tightening the cast
5. When the button is pressed, another reading from the strain gauges and translation to the degree position is taken and compared to the baseline
6. Based on the variation from the baseline, the servo motor will rotate to return the cast back to the baseline value, and the servo's new degree position is recorded
7. LCD displays the current heart rate of the patient, along with the new servo position if changed above
8. Repeat the code from step 3

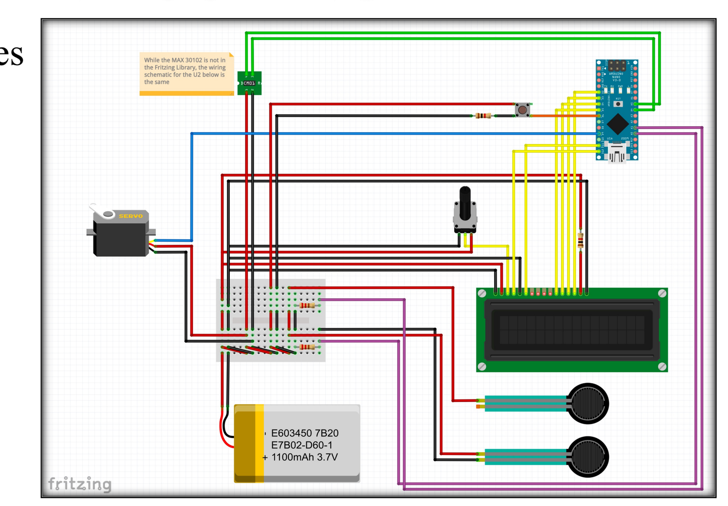


Figure 4: Fritzing Diagram of System

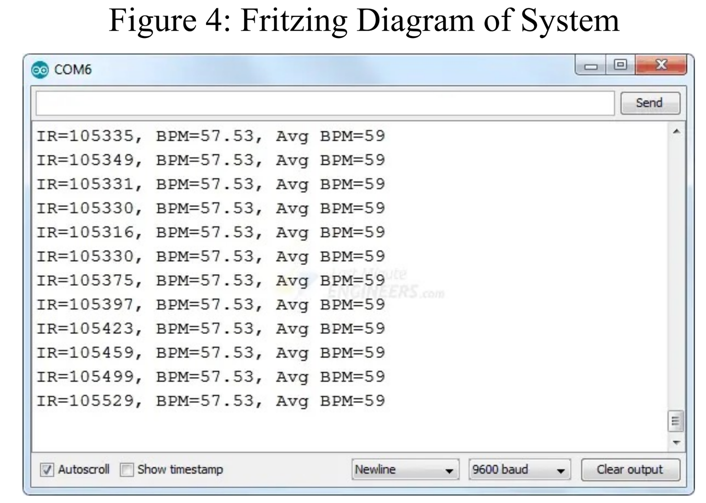


Figure 5: Serial Monitor of Arduino Calculating Heat Rate (Step 3)

TESTING AND RESULTS

Testing after assembly and wiring included:

1. [Pre-Code] Calibration Strain Gauges, Servo Motor, and Pulse Oximeter to make sure wiring was successful
2. [Code Part 1] Baseline Test on Patient's Arm to maintain pressure overtime (1 hour per test)
3. [Code Part 2] Testing of Pulse Oximeter to detect patient's BPM and activation of servo motor to adjust tightness if heart rate is not in the 65-110 BPM range
4. [Code Part 3] Testing of Baseline Pressure deviation detection from Strain Gauge and adjustment from servo motor

Testing after assembly and wiring included:

- LCD Display needed adjustment from potentiometer
- Adjustment needed a long period to tighten
- Loosening of the cast felt more jolted than the tightening procedure

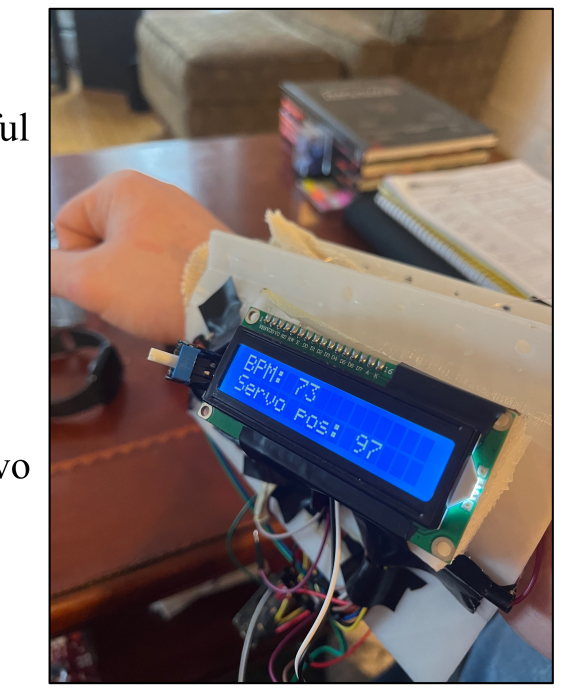


Figure 6: Arm Cast Placed on Achilles' arm performing a tightening calibration to return to baseline tightness

FUTURE WORK AND CONCLUSIONS

- Fabricate a third layer to protect and conceal the wiring and electronics.
- Fabricate the hand section so the cast can provide proper fixation of the wrist.
- Further testing on the long-term durability and functionality of the splint.
- Further testing for optimal strain gauge placement
- Improvement of motor adjustment time

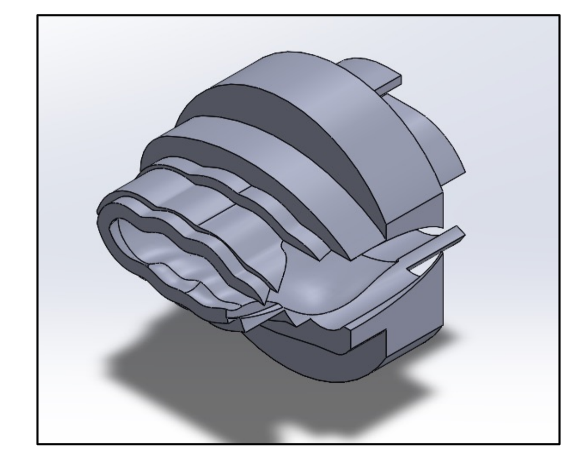


Figure 7: Proposed CAD Model of Hand Section

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[2] The Center Oregon. (2022, November 11). What to expect when you get a cast. The Center - Orthopedic & Neurosurgical Care & Research. https://www.thecenteroregon.com/medical-blog/joint-injury-cast-care/

[3] R. Huggenberger and M. Detmar, "The Cutaneous Vascular System in Chronic Skin Inflammation," J Investig Dermatol Symp Proc, vol. 15, no. 1, pp. 24–32, Dec. 2011.