Weight-Bearing Sensor

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Introduction

Motivation:

Create an accurate, adjustable, and comfortable sensor, able to be worn throughout a physical therapy session.

- Increase accuracy in applying prescribed weights
- Fit all patients regardless of foot size or swelling

Fig. 1 STAPPONE rehab, an insole that tracks weight-bearing over time. Allows users to set weight-bearing limit in an app and receive visual, haptic, and acoustic feedback in case of under or overloading. Specific to one shoe size. Priced at €499 [1]

Background:

During rehabilitation after a lower limb injury or surgery, percent weight bearing refers to the amount of body weight a patient is allowed to place on the affected limb while standing or walking.

In physical therapy sessions, patients are led through stages such as:

- Non-weight bearing (0%)
- Partial weight bearing (25–50%)
- Full weight bearing (100%) [2]

Gradually increasing these percents helps restore strength, balance, and mobility while minimizing the risk of re-injury or delayed healing. [3] However, these percents are often applied inaccurately due to a lack of an adjustable, accurate method of measuring them.

Design Specifications

- Accurately measure the weight applied within 1-2 lbs for every 100 lbs
- Battery must last for up to 2 hours
- Function in warm and humid conditions, in temperatures from 37-40℃
- Adjustable for any size foot
- Comfortable to use, not altering the patient's natural gait
- All electrical components enclosed in the strap, not to come into contact with patient skin
- Durable, ideally lasting for several years of use
- Manufacturing costs must be under $500
- Device should be as invasive as possible, including minimizing wiring

Modeling and Testing

Modeling and Ergonomics:

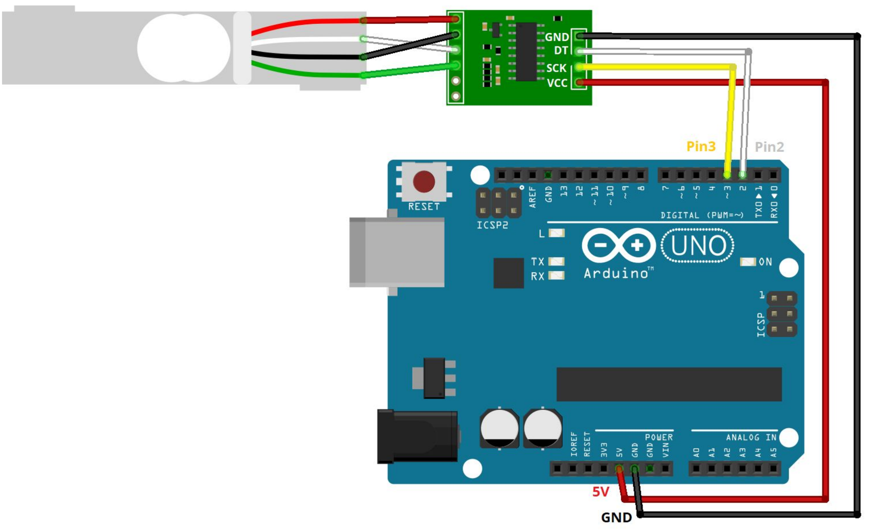

Fig. 2 Final design of the microcontroller circuit

The microcontroller will serve to record and analyze the output from the load cell using the HX711 amplifier

- Amplifier necessary due to low levels of voltage from load cell
- Microcontroller will analyze the signal and interpret to convert to usable info
- Built in low energy bluetooth function will project to screen

The ESP32 screen will receive data via bluetooth from the microcontroller-load cell circuit and use this data to print the weight values in real time

- Built in bluetooth functionality and microcontroller in the screen
- Screen will clip onto walker or sit on a surface and allow for live readings

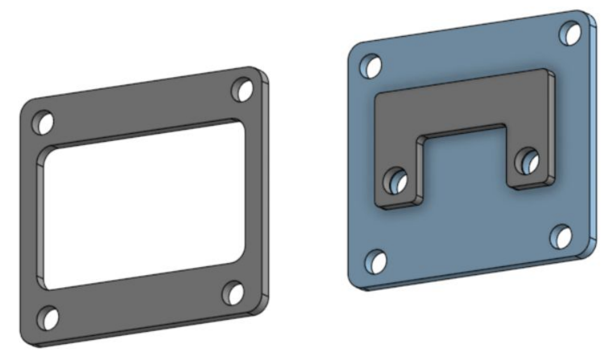

Fig. 3 Solidworks assembly of platform for load cell to allow for deflection

This platform is used on either side of the load cell, with the hollow and protruding sides allowing it to deflect when weight is applied.

The design includes:

- Rounded edges and corners for comfort
- A shape and size closely matching that of the load cell to minimize material under the foot.
- Made of acrylic to minimize profile while retaining strength.

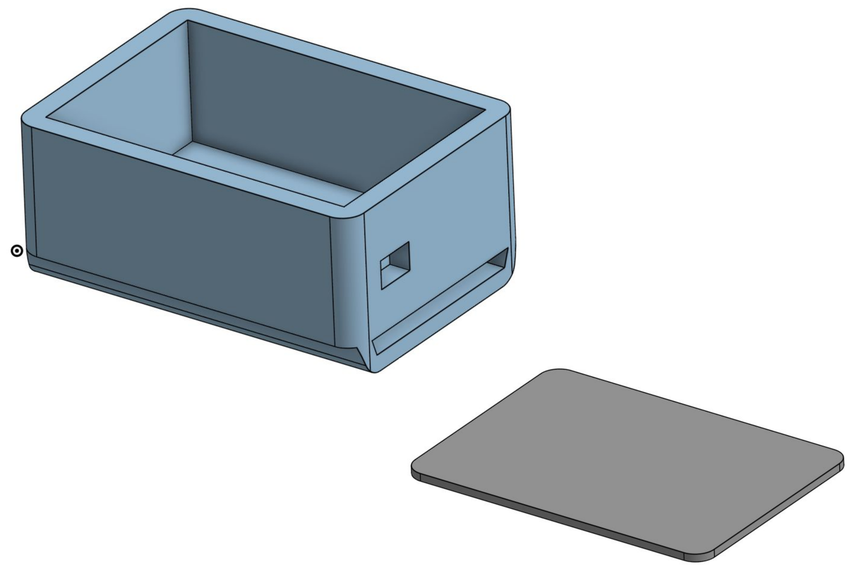

Fig. 4 Solidworks assembly of 3D printed ankle band box with a lid

This enclosure will hold the contents of the microcontroller and arduino. It also has a slit at the bottom to weave through a velcro strap to wrap around the patient's ankle.

This design includes:

- Filleted edges to give a sleek look
- Hole for the wiring
- Lid to be screwed shut
- 3D printed with an SLS printer for durability

Testing Protocol:

Testing was performed using barbells and weights in at 3 set weights

- 45 pounds, 65 pounds, 110 pounds
- Additional control measurement with zero weight
- Set measurements were used to ensure accuracy
- Lower weights were used to mimic low weight bearing requirements where device is most useful

Testing Results:

While the measurements were not perfect, the main adjustment will be simple code alterations, and the level . These measurements are promising but could be greatly improved upon with more testing.

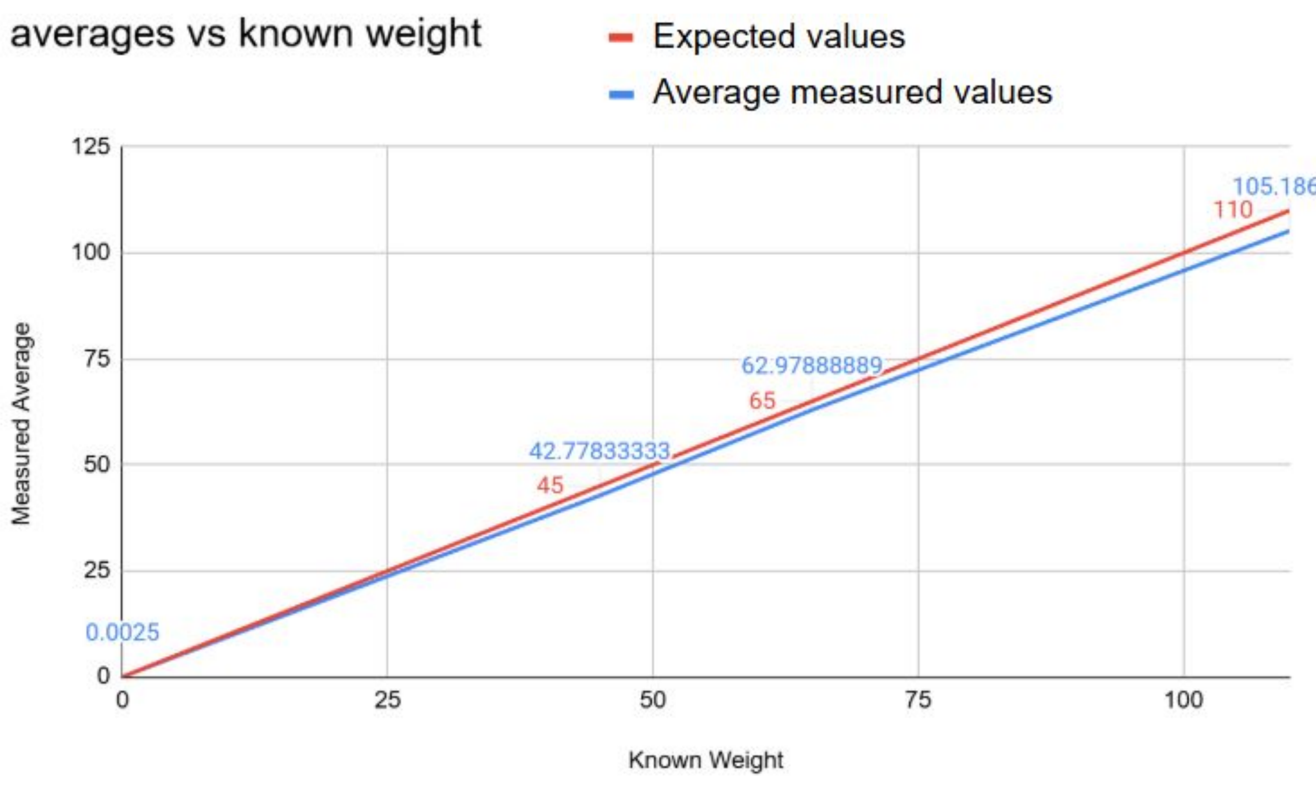

Fig. 5 A graph depicting a comparison of known weights applied vs. the average listed on the readout.

Final Prototype

The final prototype of the device includes a strap to hold the sensor and the circuitry running it, and a separate display screen. While the bluetooth functionality is not implemented, the sensor can read weights and provide output to a computer.

- Fully assembled strap
- Working screen and sensor circuit
- Sensor can output data to a computer
- Bluetooth not yet integrated

Fig. 6 Picture of final prototype

The individual pieces of the prototype are all working independently of each other, and have shown efficacy in function, simply needing work towards integration.

Future Work & Discussion

The prototype design includes most of the desired functions, thought not connected to each other. Refinement and combination of parts will be the focus of next steps.

- Screen adjustments
- Bluetooth integration
- Box enclosures around screen and circuit
- Incorporate sanitary precautions
- Power circuit by alkaline batteries

Future work on our design would center around improving our product's maneuverability and ease of use. Switching out wiring for Bluetooth, lessening our design's bulk, and changing the power source to portable batteries would be key priorities.

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References

[1] "STAPPONE Rehab," stappone. Available: https://www.stappone.com/en/products/partial-weight-bearing-management/stappone-rehab/.

[2] contributors Physiopedia, "Weight bearing," Mar. 16, 2023. Available: https://www.physio-pedia.com/Weight_bearing

[3] A. M. Eickhoff, R. Cintean, C. Fiedler, F. Gebhard, K. Schütze, and P. H. Richter, "Analysis of partial weight bearing after surgical treatment in patients with injuries of the lower extremity," Arch Orthop Trauma Surg, vol. 142, no. 1, pp. 77–81, 2022, doi: 10.1007/s00402-020-03588-z. Available: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8732824/.