Just by the Feel of a Hand

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I. Abstract:

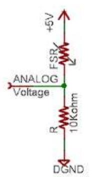
A 3D printed robotic hand is designed and fabricated to mirror the movement of the human hand and to detect the applied force, pressure and weight of an object. The robotic hand controlled by flex sensors integrated using wearable technology is primarily 3D printed using PLA materials, features individually modeled finger sections which are wired through and connected to servo motors in the forearm. An Arduino Uno controlled board is used to control the servos with signals received from flex sensors made of piezoresistive fabric and conductive wires. These sensors are integrated into a non-conductive glove with an attached Bluetooth module to facilitate the wireless communication between the glove and the robotic hand in enabling intuitive manipulation movements. Implementing the Wheatstone Bridge principle, a strain gauge-based sensor is integrated into the hand's palm to detect the applied force and pressure, enabling the display of the object weight on the LCD screen. This innovative design offers potential applications in manufacturing, robotics, human interaction systems, etc.

II. Objectives

In this study, two types of sensors, a piezoresistive sensor and a strain gauge-based sensor will be used and tested on the robotic hand for accuracy and stability in measuring weights of objects.

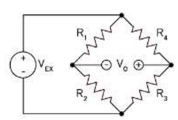
III. Background

A piezoresistive sensor or a Force Sensing Resistor (FSR) is a resistor which can qualify applied forces based on the changes in its electrical resistance. FSR is made of two membranes with a spacer. One membrane consists of interdigitated traces which are electrically isolated from one another, while the other membrane is coated with resistive ink. As force is applied, active elements come in contact with the semiconductor, and as a result, the resistance gets smaller. To measure the resistance change, a voltage divider is used as the output voltage is proportional to the inverse of the FSR resistance.



$$V_o = V_{in} \times \frac{R}{R+FSR}$$

A Voltage Divider's Expression



Wheatstone Bridge

A strain gauge-based sensor utilizes the principle of the mechanics of materials to measure strain caused by stress or force on a material. As the resistive element stretches or compresses, the length and the cross-sectional area of the element changes which results in resistive change. To measure this small change, the Wheatstone Bridge method is utilized. The bridge is made of two voltage dividers with a common voltage source.

IV. Methodology

The FSR was connected to a 10-k resistor in series on one end and 5V on the other end as shown in the setup from figure 1. Using Arduino Uno as the microcontroller and a 16 x 02 LCD screen as a display, analog readings were obtained in corresponding to different tested weights. Six data points corresponded to six known weights and their analog readings were collected to calibrate the FSR. The correlation was, then, used to test with different weights, 1 pound, 2 pounds, and 3 pounds whose values were recorded every two seconds.

For the strain gauge-based sensor, half-bridge load cells were used for the study. The first setup tested with only one load cell and two 1 k resistors. They were, then, connected to an HX711 amplifier module, the Arduino microcontroller, and the LCD screen. The load cell was, then, calibrated with a 9-pound weight to get the calibration factor which was then used to weigh different objects, 4 ounces and 9 ounces whose values were recorded every two seconds. The same setup was repeated for the two half-bridge load cells.

V. Data

Figure 1: The Relation between Analog Readings and Known Weights (lbs) for FSR Calibration

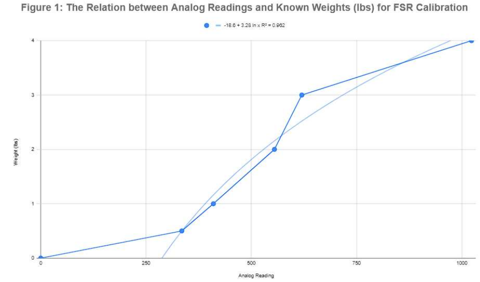


Figure 2: FSR Output Values of the Given Weights

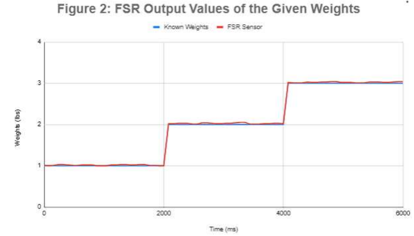


Figure 3:Weight Measurements from One Load Cell and Two Load Cells Compared with the Actual Weights

VI. Results

In terms of obtaining the readings, it was harder to get measurements from the FRS sensor compared to the load cells since the FRS's sensitive surface was smaller; however, when the loads were concentrated onto the surface, FRS offered more accurate readings compared to the load cells. In short-term measurements, its outputs were less than 3% errors with less tendency in drifting over the time as shown in Figure 2. Its high sensitivity allowed it to pick up the applied weight promptly and stay still with a tolerance of about ± 0.03 lbs. in a short amount of time, 2 seconds, without any disturbances.

Compared to the FSR, the load cell readings fluctuated more in both setups. However, out of the two setups, the readings from one half-bridge cell and two resistors seemed to be less stable and accurate compared to the readings from two half-bridge cells. This could be due to the low quality of the resistors, which added a lot of noise to the system leading to the fluctuation of the outputs. Replacing the resistors with another half-bridge cell in the second settings offered more accurate readings with tolerance of ±1.5 ounces but could not avoid the drifting effects over a short period of time. Both load cell setups took additional time to get back to zero when unloaded. This unusually high sensitivity from the load cells could be due to soldering effects, cheap materials, or high resolutions of HX711 modules.

VII. Conclusions

In terms of economics, both FRS and half-bridge cells offered much more competitive prices compared to other types of sensors. In terms of accuracy, FRS offered more accurate readings in quick, short-term measurements compared to the half-bridge load cells despite its highly sensitivity with external disturbances, and non-concentrated loads which makes it hard to maintain on a robotic hand. For more stable, accurate and reliable measurements, more expensive load cells would offer better quality, more accurate readings with lower tolerance values over a longer period. The most practical method of measurements on robotic hands required better quality sensors and research time beyond one semester.

VIII. References

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