The Smart Hand cast.

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Introduction

Tommy John surgery is a type of treatment for the ulnar collateral ligament (UCL) inside of the elbow. This type of surgery is typically used for professional or competitive athletes who may injure themselves playing baseball, javelin, or football. After such surgery, physical therapy and rehabilitation are needed to restore the patient to full health [1]. This device is intended to monitor and ensure that the patient stays within the necessary physical thresholds to recover properly. When the patient handles objects beyond the threshold limit for weight, the force sensors on the fingertips trigger the buzzer to go off to notify the patient to release the excess amount of weight. When the patient's elbow goes beyond the allowed angle of motion, this will similarly notify the patient through the buzzer.

Final Design

Figure 1 shows a system block diagram with both hardware and software. The hardware is shown in white boxes and the software is shown in blue boxes. The force sensors in the block diagram were placed on the fingertips to determine how much weight was being held. The accelerometer is being used to determine the angle at which the user's elbow is reaching to. The purpose of the buzzer is to alert the user that the angle and amount of weight being applied exceeds the threshold and should put the elbow at a lower angle or use less weight. The angle and the amount of weight applied will increase as the weeks progress in recovery.

Figure 2 shows the circuit schematic of the rehabilitation device. The force sensors were connected as a voltage divider with a 1000-ohm resistor to the Arduino microcontroller. The accelerometer was connected to the Arduino only using the z axis and the power supply. The buzzer was connected to a digital pin to the Arduino with a 1000-ohm resistor.

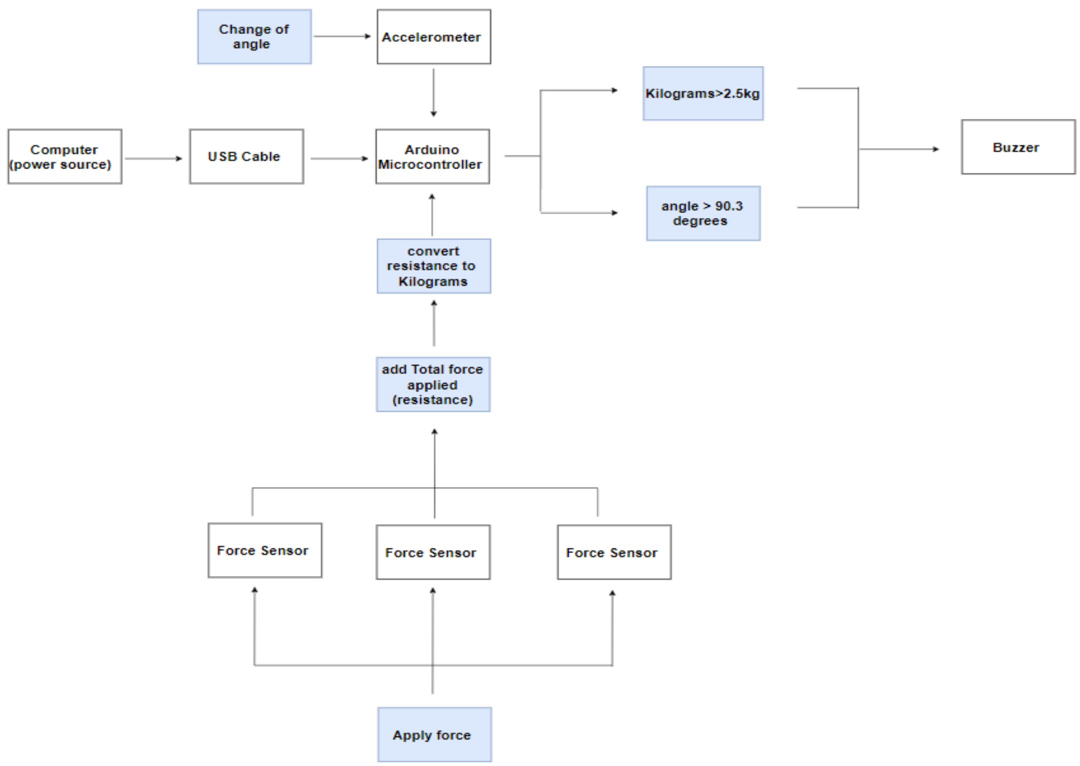

Figure 1: System Block Diagram

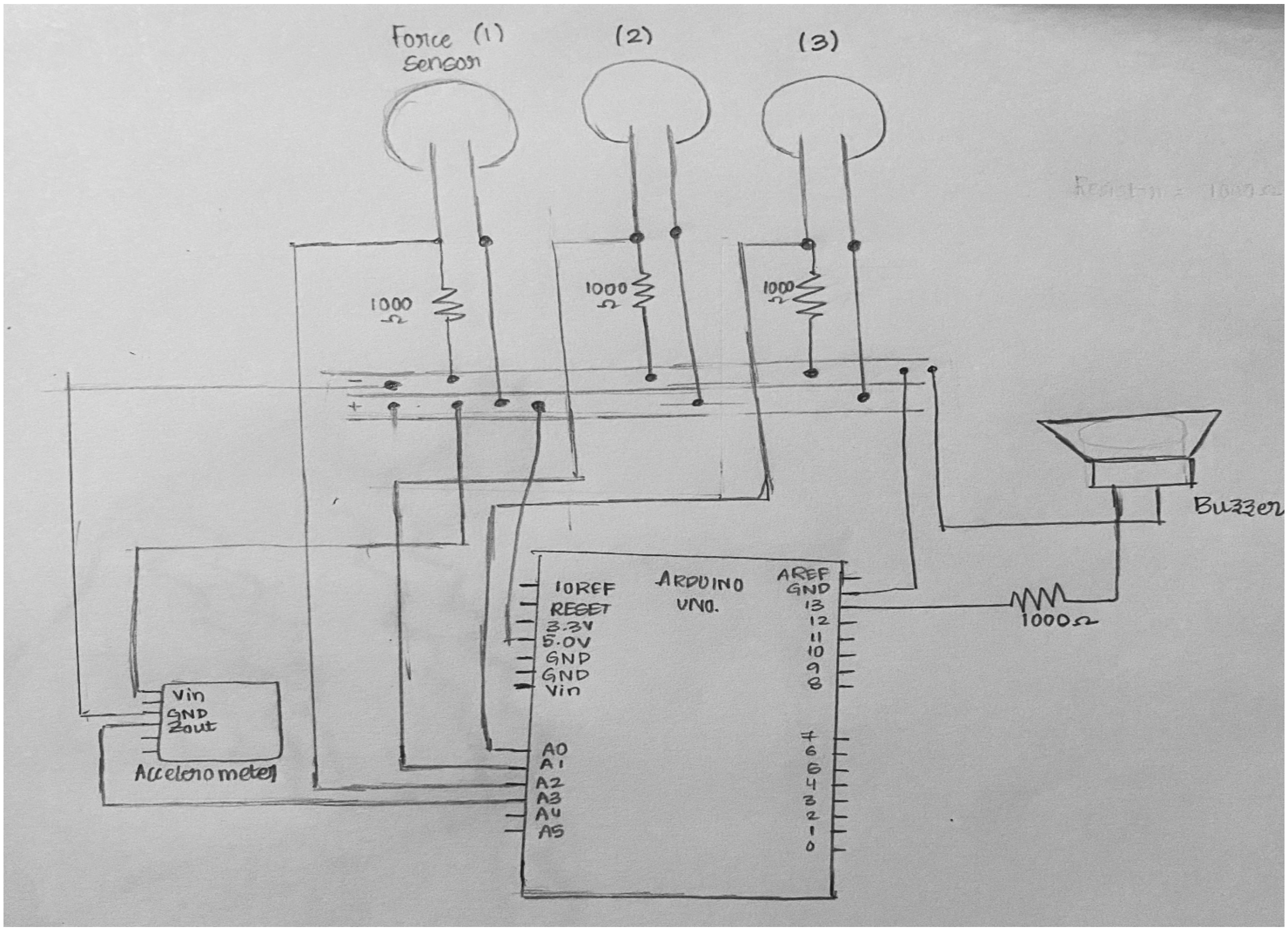

Figure 2:Circuit Diagram

<u>Materials List:</u>

- Glove
- 3 force sensors
- Accelerometer
- Wires
- Cardboard
- Tape
- Buzzer
- Computer (power source)
- 3 1k Resistors

Final Results

To use the device, the user will wear the glove with the force sensors aligned with their fingertips and the breadboard and Arduino on the top of the hand. The beginning position should be a natural resting orientation to allow the sensors to set this beginning location to zero. Once moved in an upward or downward direction on the z-axis, the buzzer will go off once the arm exceeds the set threshold. When holding or gripping an object with a certain amount of force, the buzzer will also go off once the number of kilograms exceeds the set limit.

The signal is received through the force sensors as it is connected through the analog pins on the Arduino. We programmed a beginning value of zero to be the neutral weight limit. From there, once force is applied, this signal is converted into a voltage and calculated into kilograms. We set a value of 2.5 kg to use as a reference for excessive weight. Similarly, the accelerometer is wired to another analog pin and is first calibrated with the z-axis aligned to 0°. The threshold is set to 90.3°. The buzzer is wired through a digital pin and communicates with the rest of the circuit through the Arduino code. Once either the force sensors or accelerometer's detected value goes beyond the set limit, this will trigger the buzzer to emit an audible signal.

The testing and validation procedures we've conducted included running the code and trying different motions and orientations to see if the buzzer and accelerometer's relationship was assembled correctly. For the force sensors, we applied different tests to monitor the changes in value the sensors were reading and comparing with the actual weight values of the objects. Regarding the power source, we used and tested our device with both the Arduino connected to our laptops as well as with a 9V battery. During these tests, our device was able to properly pick up the detected excess angle of motion to notify the buzzer.

Conclusions and Further Refinements

Our device was able to buzz according to our thresholds. As the fingertips carried more than 2.5kg or the angle would reach 90.3 the buzzer would emit a loud sound. An improvement that would help our design is to calibrate the force sensors. In the code, the force sensors were directly read by analog read and were added together to get the total force. The total force was then converted to kilograms by using the equation given to us from the datasheet. Even though the equation is ideal for all force sensors, collecting a calibration equation would have helped the force sensor determine the amount of weight the fingertips held more accurately determine weight that was being held did not always exceed 2.5kg. Another improvement that could have been made is having smaller hardware components. Most of the hardware was placed inside a cardboard box that was then mounted on top of the wrist. This made the device a bit difficult to keep steady, smaller components would help the device not be as bulky.

Appendix

```
int acceleration = A3;

float zeroAngleVoltage;

float F1=0;

float F2=0;

float F3=0;

void setup() {

Serial.begin(9600);

pinMode(acceleration, INPUT);

pinMode(A0,INPUT);//F1

pinMode(A1,INPUT);//F2

pinMode(A2,INPUT);//F3

pinMode(13,OUTPUT);//buzzer

digitalWrite(13,LOW); //buzzer

zeroAngleVoltage = analogRead(acceleration) * (5.0 / 1023.0);

}


void loop() {

delay(10);

// Read analog value from Z-axis

int sensorValue = analogRead(acceleration);

// Convert analog value to voltage

float voltage = sensorValue * (5.0 / 1023.0);

// Normalize the voltage relative to the reference voltage

float normalizedVoltage = voltage - zeroAngleVoltage;

// Calculate the angle using arccosine

float angleZRad = acos(constrain(normalizedVoltage / 5.0, -1.0, 1.0));
```

```
float angleZDeg = angleZRad * (180.0 / PI);
//Read Force sensors
 F1=analogRead(A0);
 F2=analogRead(A1);
 F3=analogRead(A2);
//add total force
 float totalForce=(F1+F2+F3);
//convert total force to kilograms (equation from the data sheet)
 float kg=((log((totalForce/336.04))/-.712)*(-1));
//threshold picked
if(kg >2.5 || angleZDeg > 90.3){
// buzzer goes off
digitalWrite(13,HIGH);
 }
 else{
//buzzer does not go off
 digitalWrite(13,LOW);
}
delay(200);
}
```

References

[1] C. C. medical professional, “Tommy John surgery: Details & recovery,” Cleveland Clinic, https://my.clevelandclinic.org/health/treatments/25117-tommy-john-surgery (accessed Nov. 15, 2023) https://my.clevelandclinic.org/health/treatments/25117-tommy-john-surgery