Advisor: Dr. José Luis Contreras-Vidal, Department of Electrical Engineering
University of Houston - Houston, TX

Objective

To create a soft robotics exoskeleton that assists patients with foot drop by lifting and lowering the foot based on their walking pattern.

Background

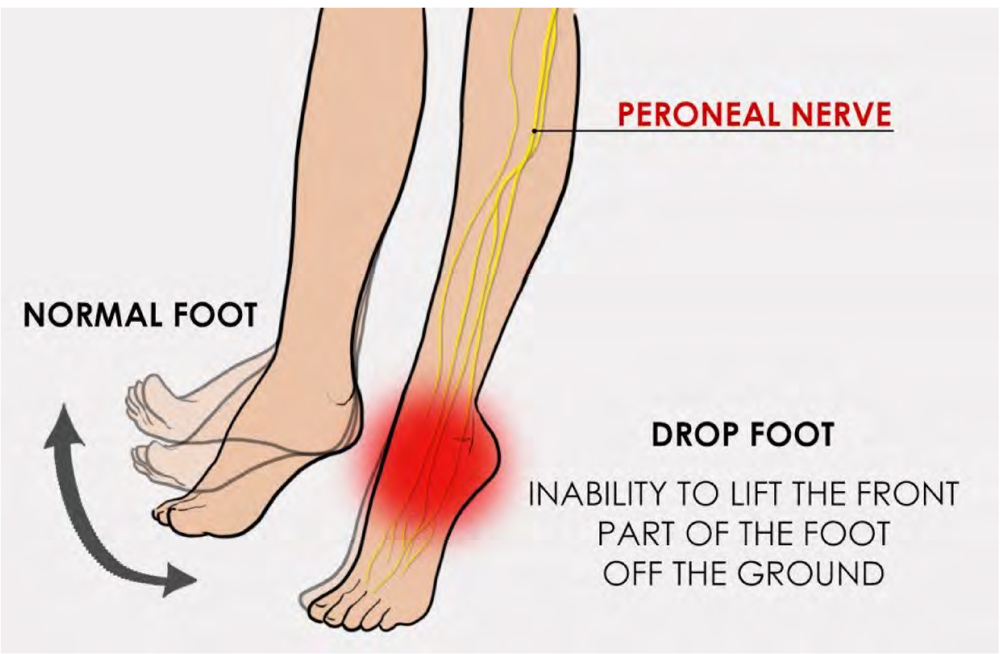

Figure 1. Foot drop

- Foot drop is a condition where individuals are not able to lift the front part of their foot. This usually happens as a result of weakness or paralysis of the muscles that control dorsiflexion
- Patients with foot drop have a complication with clearing their foot at the same time as they are walking; this causes them to drag their foot on the ground
- They develop what is called a steppage gait in which they bend the hip and knee exceedingly in order to raise the foot higher; this can also lead to a foot slap where the patient slaps their foot down on the ground as they proceed to walk. The risks develop slower walking, fatigueness, higher energy required, pain, falling, tripping, and frustration among the patients.

Methods

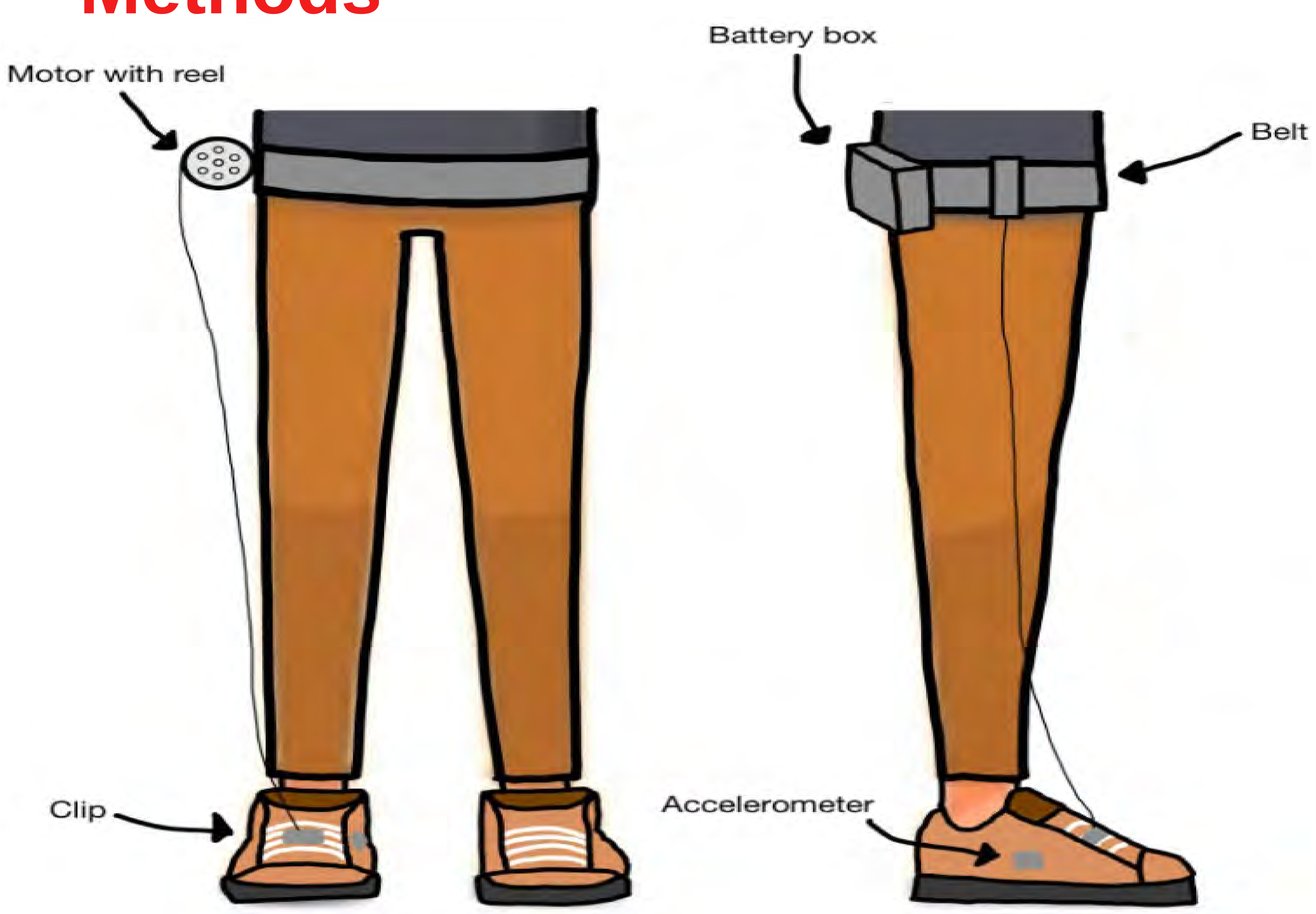

Figure 2. Design Layout

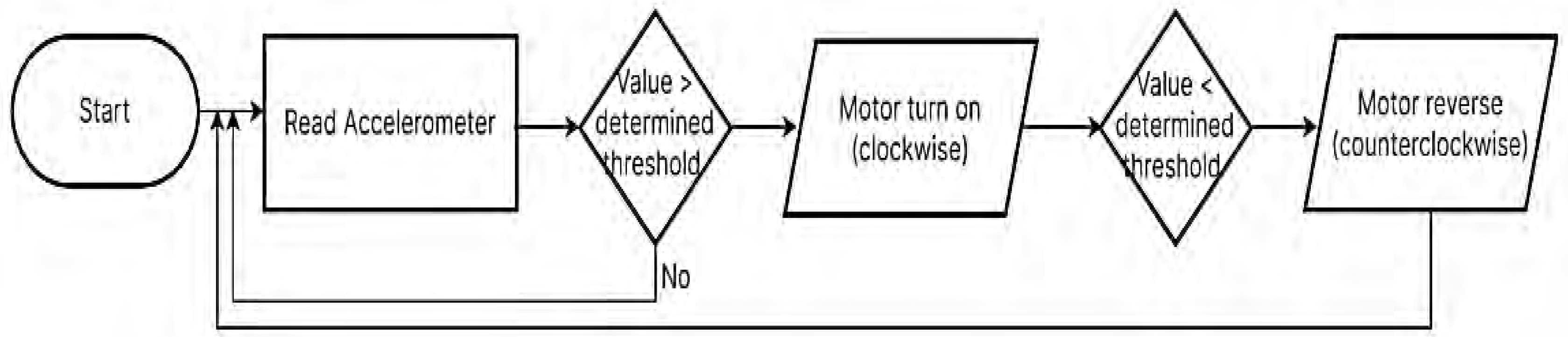

Figure 3. Flowchart of accelerometer process

In Figure 2, we created a cartoon for the layout of our design. In this cartoon we have been able to easily indicate where each component will sit on the patient. We have threaded a belt through the motor housing and battery box, with the motor on the right hip and the battery box on the back of the patient's belt. In the battery box we have put a 12V DC power supply, an Arduino, and a small breadboard with the components. All the housings were 3D printed to custom fit the patient and to minimize the overall profile.

The motor, along with the 3D printed spool, is placed inside a motor housing that contains a gap. A nylon cord is attached to both the spool and the patient's shoelaces.

The final component in our project is the accelerometer, which is attached to a clip and placed at the heel of the patient's shoe for ease of use. This accelerometer is then connected to a cable that relays back to the battery box.

Figure 3 shows the process of the accelerometer. Our devices uses an active accelerometer that is clipped onto the patient's heel. This accelerometer detects movement as the patient begins their gait cycle. Once the patient begins to move the accelerometer data gets processed by the Arduino.

Once the patient begins their walk cycle, the DC motor is turned on and rotates clockwise lifting the toe of the patient through a cable.

The Arduino then waits and verifies that the accelerometer is in the second position where the motor spins counterclockwise, releasing the foot and putting it down in a neutral position again. The cycle resets and restarts accordingly.

Results

Throughout our experimenting and testing, we were able to successfully detect the beginning of the patients walk cycle consistently. In Figure 5, it is shown that as the red line begins to peak, this is indicating the heel is beginning to be lifted. This is the indicator we then used to activate the motor.

Figure 4. Walking cycle

Figure 5. Raw Data from accelerometer

Similarly to being able to detect our Y axis movement (lift), we also were able to detect the positive X axis movement (or forward distance). Using these two X and Y movements we were able to detect when the foot was being lifted, and when the patient had finished moving their foot forward completing the walk cycle.

In Figure 4, we can see the prototype working. In the first image, the patient's heel lifts, which activates the motor. In the second image, the patient has had their toe by the cable, successfully preventing the dragging of the toe. Then finally in the third image the motor is reversed, and the foot is placed back into a neutral normal position ready to start the cycle again.

The previous group used a stepper motor. but it was not strong enough. Therefore, we used the DC motor for this application, and it allowed us to lift the foot around 5 degrees with significantly more torque availability.

Conclusion

- The physical specifications of the prototype were tested and verified to withstand the forces applied by the motor
- Compared to the previous group, our design maintains a slimmer profile. We also had the device successfully lift the foot of about 5 degrees or higher ($\geq 5°$) with a new powerful DC motor and a spool system.