



### Abstract

Many medical conditions result in decreased mobility. However, reliance on canes, crutches, or related mobility aids over long periods of time causes muscle strain on other parts of the body such as the wrists or forearms. One method of improving quality of life with chronic decreased mobility is the use of lower-limb robotic exoskeletons. Typically, these exoskeletons have both legs; however, not all patients who suffer from decreased mobility require support for both legs. Despite this, most single-legged exoskeletons are only for rehabilitation purposes. This research explores a non-traditional single-legged, lower-limb robotic exoskeleton design for activities of daily living. By using an exoskeleton, the load of the human body while walking is handled by the exoskeleton rather than the affected limb. The exoskeleton should match the original gait of the patient.

### Background and Goals

Approximately, 20 million Americans suffer from diabetic neuropathy as of 2024 [1]. Diabetic neuropathy can lead to muscle pain, weakness, and loss of muscle strength throughout the legs [2]. This project targets those affected by diabetic neuropathy in the lower-body region, affecting their ability to walk. As more people become affected by diabetic neuropathy, including our customer, the need for specialized mobility aids become more prevalent. One such example of a specialized mobility aid for the lower body is a daily-use, single-legged lower-body robotic exoskeleton. However, current single-legged exoskeletons are primarily used for rehabilitation purposes and are not optimized for everyday life. Control of these exoskeletons typically involve electromyography (EMG), which measures muscle activity using electrodes placed on the skin.

This purpose of this project is to develop and manufacture a single-legged, lower-limb robotic exoskeleton. The goal of the exoskeleton is to assist a patient with variable strength for activities of daily living. It should match the original gait of the patient, as well as allow for adjustable assistance levels. Overall, the main goal is to allow a patient to walk comfortably despite decreased mobility.

### Electrical and Hardware Design

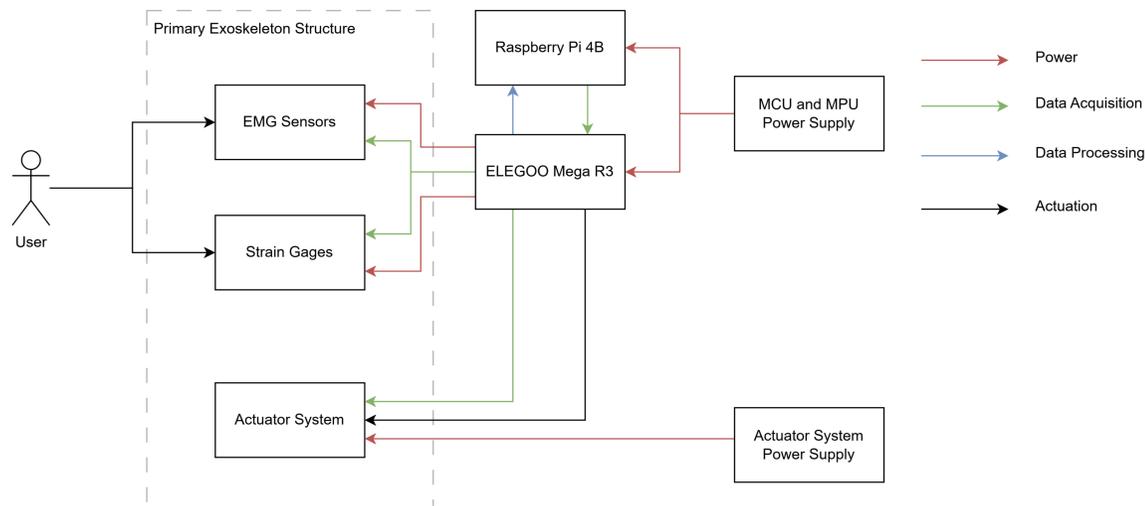


Figure 1: High-Level System Overview

The exoskeleton uses ELEGOO MEGA R3 and a Raspberry Pi 4B as the microcontroller (MCU) and microprocessor (MPU) respectively. Strain gages measure the joint stress of the exoskeleton during operation. The linear actuators move based on EMG readings, which are then processed by the Pi. The Pi communicates this processed data to the ELEGOO, which controls motion. MPU and MCU communication is achieved through serial peripheral interface (SPI) protocol. EMG readings are taken using electrodes on the surface of the skin.

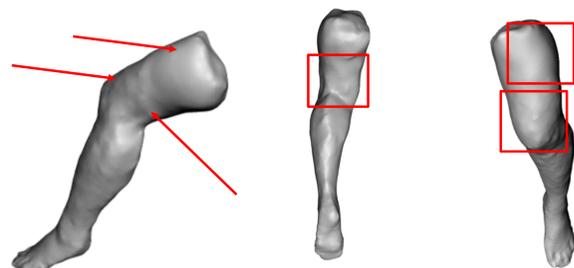


Figure 2: Electrode Placement on Bent Customer Leg

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### Mechanical Design

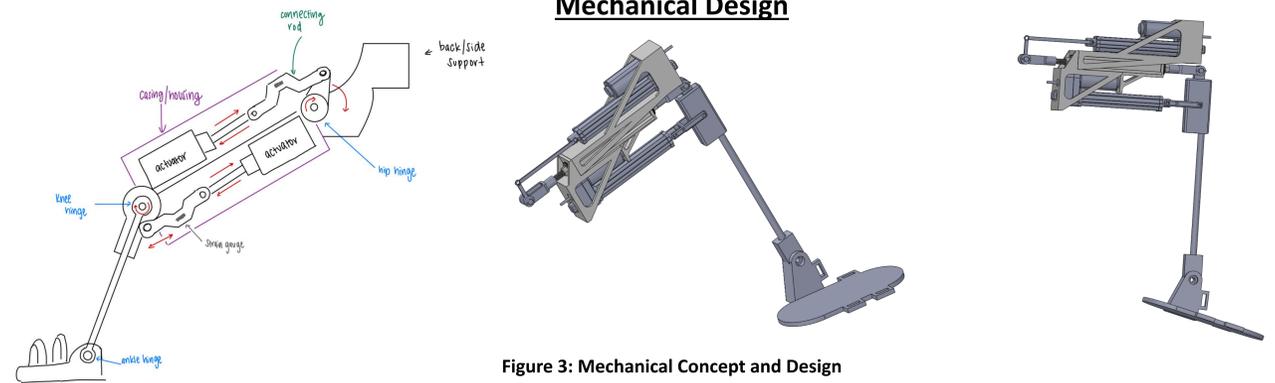


Figure 3: Mechanical Concept and Design

The exoskeleton structure must be capable of supporting a 200 lb. person throughout the course of their daily life. To do so the mechanical design of our lower-body exoskeleton provides the wearer with assistance in the hip and knee joints. This assistance is provided by a dual actuator system with slider-crank linkage connections capable of translating linear motion to rotational motion. This allows the thigh to be lifted, lowered, flexed, and extended by the user as they walk. For this to occur, two PA-10 IP68M Waterproof Linear Actuators provided by Progressive Automations were selected for its high load capacity and size. These actuators then replicate the movement of the quadriceps and hamstrings, aiding when needed, as the user walks. Strain gauges attached to the connecting rods will measure force feedback at their respective joints, enabling precise control of assistance.

For the thigh section of the exoskeleton, the linear actuators will be encased in a structure composed of PLA Tough which provides 750% more impact resistance than typical PLA. Tensile tests were conducted by our team to further justify the use of PLA Tough for the casing of this portion which proved to withstand up to 550 lbs. of force. The thigh section, which contains the actuators, and the calf support section will consist of stainless steel due to its higher strength relative to aluminum.

The lower half of the exoskeleton consists of an ankle fastener and calf support section. The ankle portion of the exoskeleton consists of a heel stop and Velcro strap to secure the user's foot. For accommodation similar methods will be utilized to secure the exoskeleton to the user with three straps on the thigh and two on the calf for proper securement. Padding will also be introduced to the thigh section to better fit the user's body for better securement.

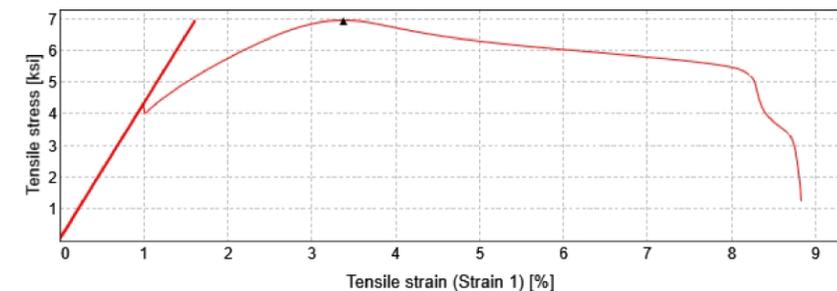


Figure 4: PLA Tensile Tests

### References

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