Lower Limb Knee Exoskeleton Device

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Introduction

Exoskeletons built in the past as well as the exoskeletons currently in the industry suffer from bulkiness, lack of robust controllability, and actuation performance. The goal of this project is to overcome these issues by developing a prototype of a lower limb knee exoskeleton through the implementation of advanced hardware and software technologies.

Specifications

The lower limb knee exoskeleton shall meet the following specifications:

- The torque output of the device shall match or exceed 25% (2.35 N·m) of the knee joint torque of the average human male (20-35 years) during walking [1].
- The user shall be able to use the lower limb exoskeleton for a minimum of one gait cycle (one swing and one stance phase) continuously.

Control System

- Consists of electromyographic (EMG) muscle sensors that were used to gather voltage signals from users hamstrings and quadriceps.
- These signals were used as input values to command the actuator to extend or retract.
- The linear actuator contains an internal incremental encoder, which was used to detect the position of the linear actuator.

Schematics

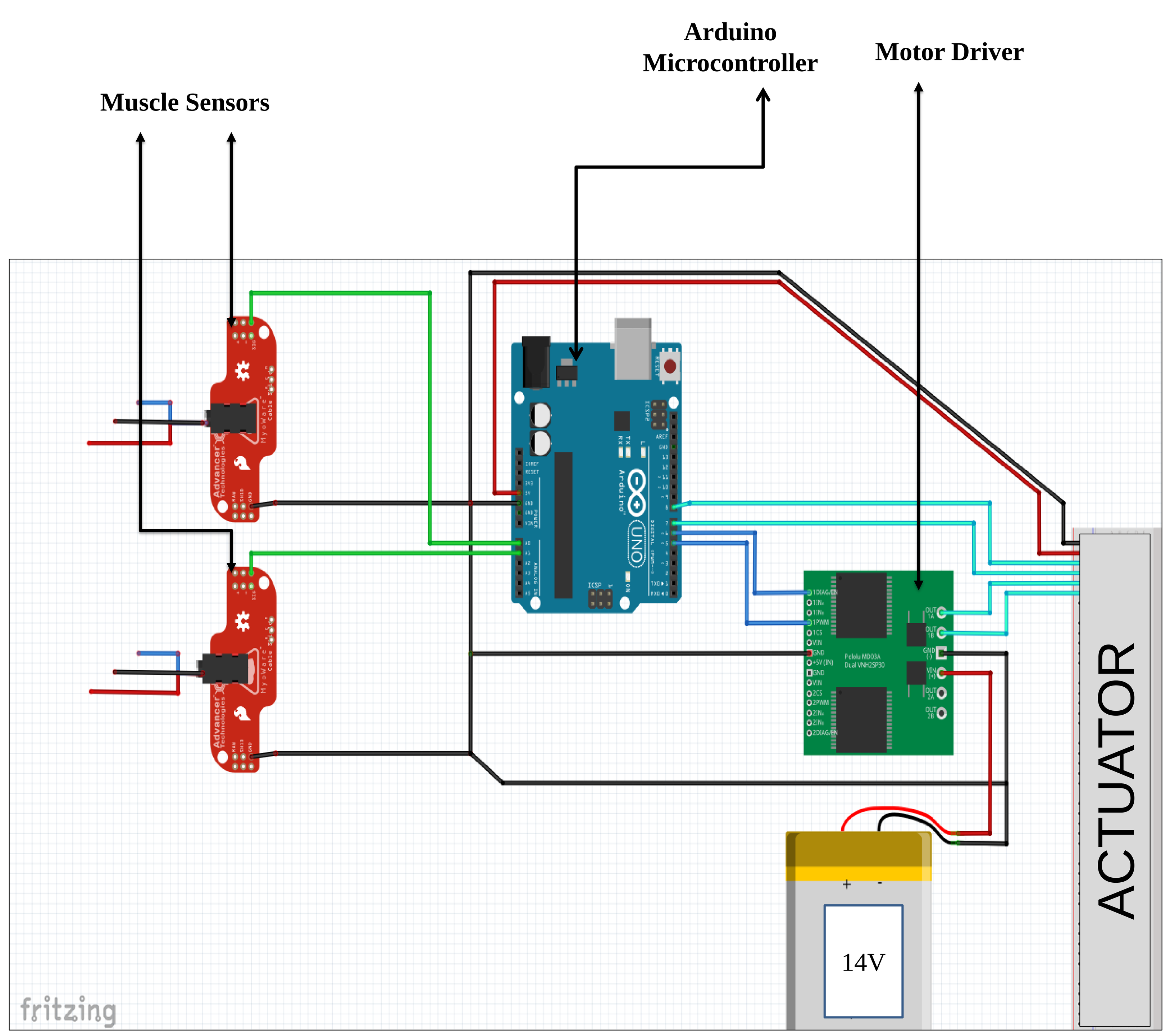

Fig. 1 Control System Schematics

Abstract

This project is the primary phase to develop a prototype of a lower limb exoskeleton through the implementation of novel hardware and software techniques that will overcome specific issues that current exoskeletons suffer from, such as lack of robust controllability, bulkiness, and actuation performance. During this phase, a knee exoskeleton with a linear actuator was constructed. It is controlled using data received from electromyography (EMG) signals. The device was designed as an assistive device for a non-handicapped person. The main requirement of the device was to match or exceed 25% (2.35 N·m) of the knee joint torque of the average human male (20-35 years) during walking [1]. Furthermore, preliminary studies on electromechanical properties of soft robotic materials have been performed in order to explore their capabilities for this application.

Design Methods

- The main device consists of a linear actuator with an internal digital encoder, and a knee brace frame.
- The device is powered by a lithium-ion polymer battery.
- The device is controlled using a microcontroller and motor driver.

Fig. 2 Device in full extension ~ 0°

Fig. 3 Device in flexion ~ 60°

Additional Research

Soft Robotics (Soft Compliant Systems)

- In order to overcome issues in the body of current bulky and rigid exoskeleton systems, studies on the electromechanical properties of electroactive polymers composites were performed in order to understand their possible capabilities into this field to create soft compliant systems.
- A polymer from the market (BJB TC5005) was mixed with different types of Nano-powders (graphite and copper) to enhance their mechanical and electrical properties.

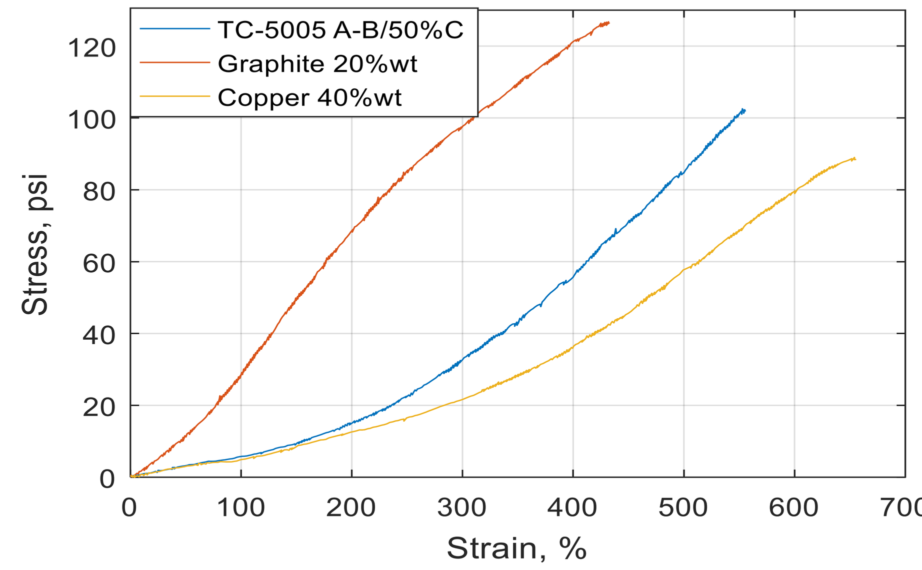

Figure 4: Stress-strain curves of plain TC-5005, graphite added (20%), and copper added (40%).

Table 1: Dielectric constant of the composited change with frequency.

Frequency (Hz)	e_r@100	e_r@1KHz	1e_r@10KHz
TC-5005 A/B-C	5.23	4.86	4.27
Copper Powder	5.25	4.93	4.13
Graphite Powder	7.14	6.91	6.74

Results

- The lower limb knee exoskeleton device was able to produce a maximum flexion angle of 60°.
- The device was able to produce a maximum measured torque of 16.95 N·m at the knee joint.
- The device torque is 180% greater than the maximum torque measured at the knee during the gait cycle without assistance (9.39 N·m) [1].
- The soft robotics research concluded that the electromechanical properties of polymers were improved by the addition of nano-materials.

Future Work

- The next phase of this project intends to develop a prototype of the ankle portion of a lower limb exoskeleton assistive device that will then be interfaced with the knee portion.

References

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[2] Yu, H., Cruz, M. S., Chen, G., Huang, S., Zhu, C., Chew, E., ... & Thakor, N. V. (2013, May). Mechanical design of a portable knee-ankle-foot robot. In *Robotics and Automation (ICRA), 2013 IEEE International Conference on (pp. 2183-2188). IEEE.*

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