Assistive Exoskeleton for the Elderly

02

Team Leader: Daniel Quintano
Team Members: Kevin Munguia, Rob Piskura, Tyler McCormack, Alec Nagucki
Industry Sponsor: Discovery Lab Global (DLG)
Industry Advisor: Dr. Rob Williams
Faculty Advisors: Dr. Dan Simon, Mohamed Abdelhady
Electrical Engineering and Computer Science Department, Cleveland State University, Cleveland, OH 44115

D.Quintano@vikes.csuohio.edu

Abstract

Design and create a lower limb assistive exoskeleton that can be harnessed to the strongest leg of an elderly person who has trouble lifting their total body weight while climbing stairs. The lower limb assistive exoskeleton should support 25% of the user's total body weight, enabling them to achieve better self-mobility. Using mechanical and electronic components, the prototype must be demonstrated with two users: one weighing 160 lbs and the other weighing 110 lbs.

Introduction and Background

- **Existing Exoskeletons**
  - Exoskeletons already exist for the military and medical fields.
  - These designs are extremely capable but are also expensive.
  - They are also built for the entire lower body and sometimes include back support.
  - A medical version for lower limb paraplegia costs around $80K.

Fig 1: Lockheed Martin K-SRD

- **The Goal**
  - Design a relatively inexpensive exoskeleton brace to assist elderly people to climb stairs ($150 per unit).
  - Design the brace to be almost completely produced with additive manufacturing techniques.
  - Supply 25% of the force needed to lift a 160 lb person.

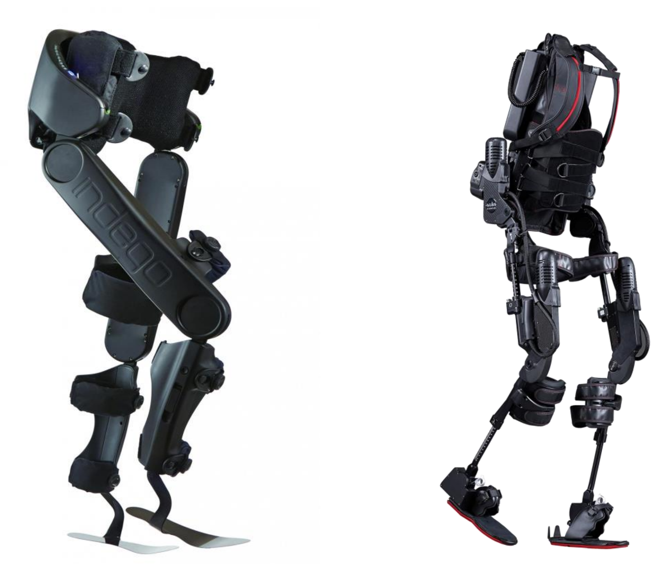

**Fig 2: Left: Parker Hannifin Indego
Right: Ekso Bionics EksoGT**

Mechanical System Design

- **System Overview**
  - The knee brace exoskeleton will be designed based on our measurements from an existing therapeutic knee brace.
  - Coding will be done in C with an Arduino microcontroller to control the stepper motor.

- **Design**
  - Solidworks was used for the design and all major components were 3D printed and used to assemble a sturdy knee brace. Only the fasteners and the lead screw rod were not 3D printed.
  - The actuation system is composed of a lead screw mechanism with a NEMA 23 stepper motor attached to a gear box.
  - The mechanism is designed to produce 118 Nm of torque at the knee joint; this number was calculated using gait data obtained through our research.

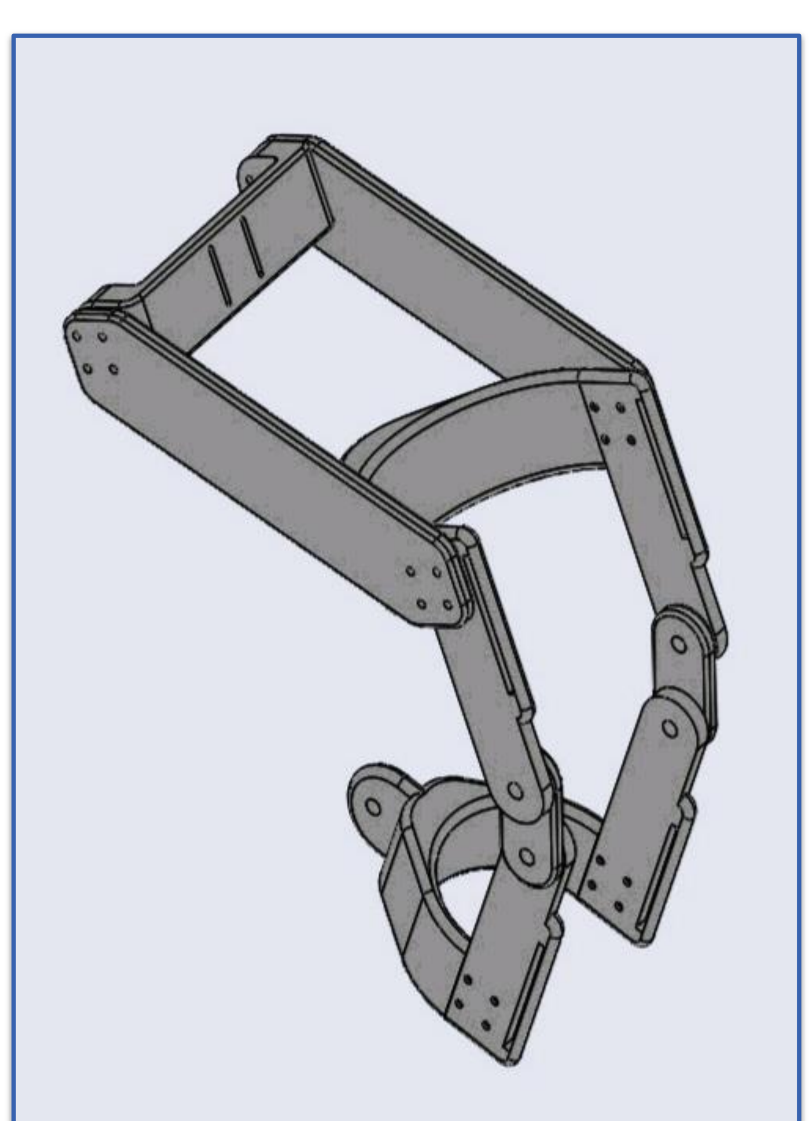

Fig 3: Exoskeleton Frame

Electrical System Design

- Using an Arduino Mega board, stepper driver and NEMA 23 motor, we designed our circuit to be mounted on the brace.
- Our motor control circuit includes push buttons, limit switches and batteries to power the Arduino and motor.
- We used a breadboard to test our design, but we had to make sure the final design would be compact. Thus, using a protoshield, a circuit was designed to snap on top of the Arduino Mega board.
- We are using a 9 Volt battery to power the Arduino board and a 12 Volt battery pack to power the NEMA 23 motor.

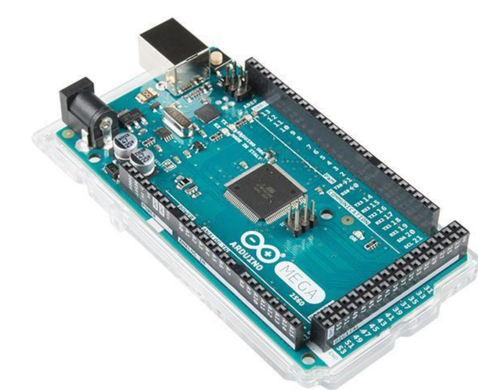

Fig 4: Arduino Mega board

Fig 5: Stepper motor driver

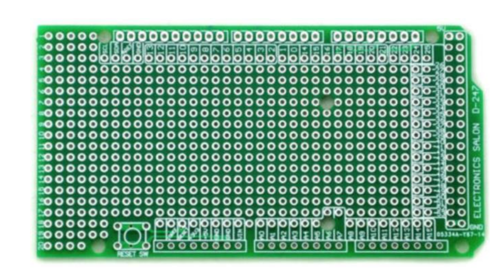

Fig 6: Protoshield for Arduino board

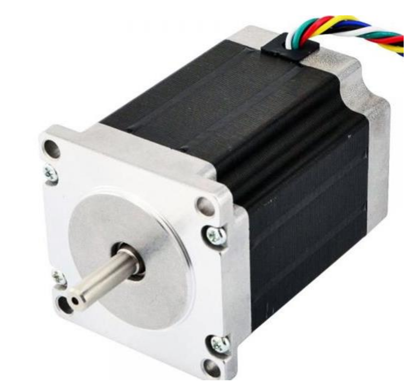

Fig 7: Nema 23 76 mm dual shaft stepper motor

Experimental Results

- **Electrical**
  - We tested the motor by using Arduino code to ensure proper control.
  - We found that 12 Volts will provide sufficient power to the stepper motor via the driver.
  - We tested motor control with buttons and limit switches.
- **Mechanical**
  - The budget did not allow for the purchase of a motor/gearbox combo with enough power and speed.
  - We designed a 3D printed gearbox to lower costs and have enough power.
  - The design works but is too slow to be practical for retail sale or effective home use.

Fig 8: Stepper Motor with Lead Screw

Fig 9: Pneumatic Cylinder

Conclusion and Future Recommendations

- Through our research, we found that a NEMA 23 stepper motor might not have the necessary torque to provide the required 25% support of a 160 lb person, but our model was the most powerful in its price range.
- Within our specified requirements, we delivered what we believe to be the most effective option, even though it may not be practical.
- We attempted to produce a full working prototype using the existing frame design, regardless of cost. Using a pneumatic actuator instead of a motor, our brace was able to support the user's **entire** weight at a reasonable speed for stair climbing.
- With additional resources, an electric actuator could be used with the existing circuitry and would allow for portability and practicality.
- In the future, this design could be adapted for other limbs with a full exoskeleton suit being the ultimate goal.