Airstep: The Design of a Walking Rehabilitation Device for Patients with Spinal Paralysis

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Overview - Design and fabricate a mobile robot that allows the gait rehabilitation of paralyzed patients while they are still in their hospital beds.

Objective - Unload the muscles of the patient's leg to allow for weightless leg motion through their full range of motion.

Challenge- Create a device that is able to support the patient's leg, provide near constant force to their leg and measure their movements.

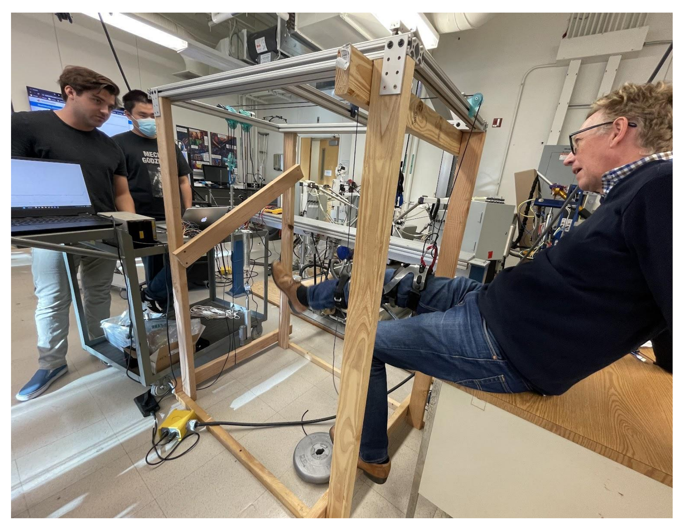

Fig 1. Final Prototype

Solution- Support the patients legs using a pulley cable system, driven by a series elastic actuator.

Existing Solution

The device currently being used by UCLA research team only fully unloads one leg at a time, and patients must be turned on their side.

Fig 2. UCLA Current Design [1]

Design Requirements

The design should be effective in passively supporting the weight of patients legs.
The device must be safe, reliable, and durable.
Should be stable and comfortable for users.
Must be fast in measurement and recording.
Must be easy to set up.
Must be under the desired budget.
Must fit the limited space in the hospital.

AIRSTEP

Final Design

Mechanical System

- Provide constant force to patient's leg
- Allow for full ROM of leg
- Adjustable for different patients

Sensing System

- Measure and record patient data and progress

Cable Placement- Patients leg will be supported from the center of each leg member to increase range of motion

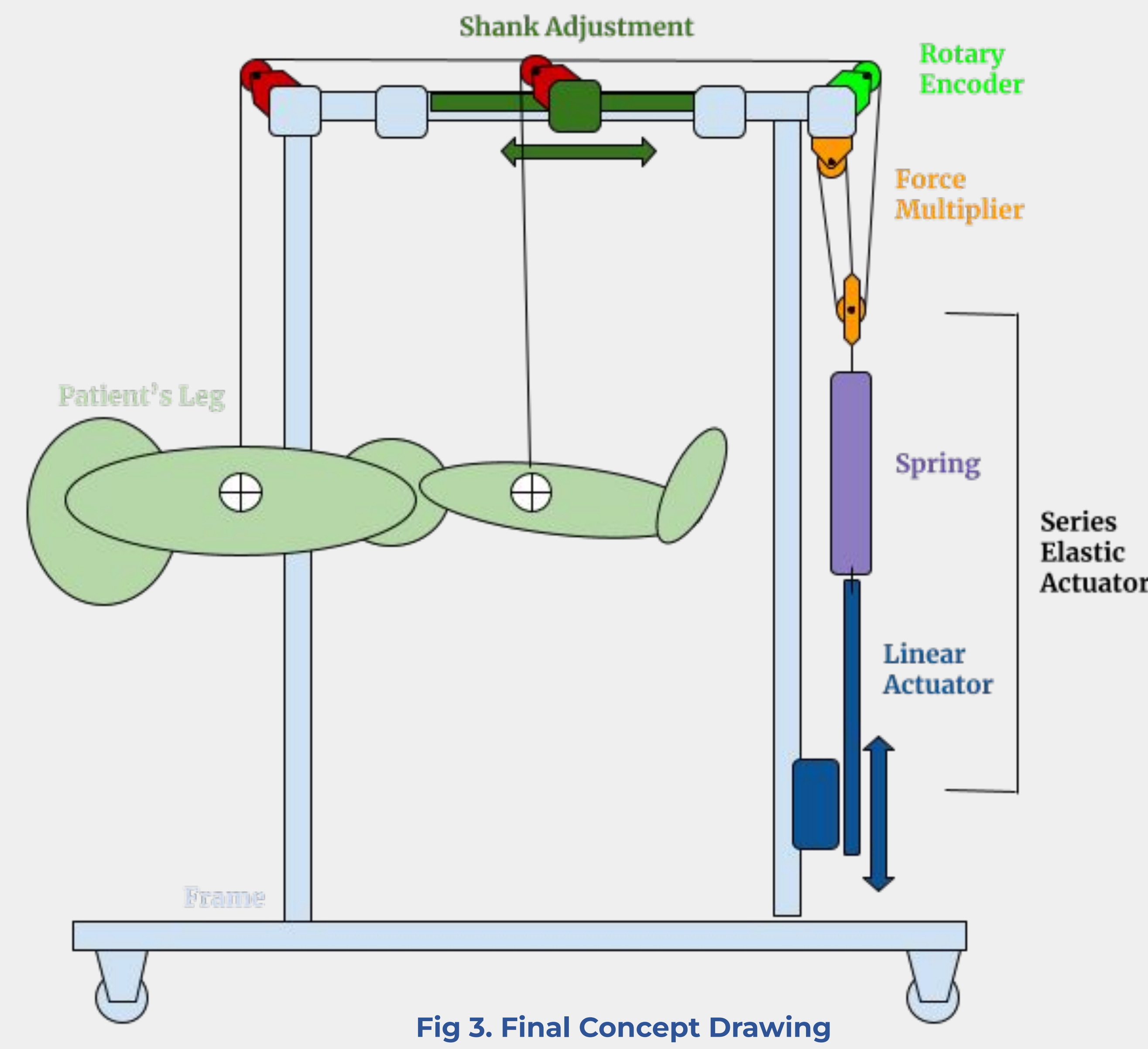

Fig 3. Final Concept Drawing

Major Components

Fig 4. SEA Prototype

Series Elastic Actuator (SEA)-

Force sensor, spring and linear actuator work together to always apply the same force, no matter the position of the leg

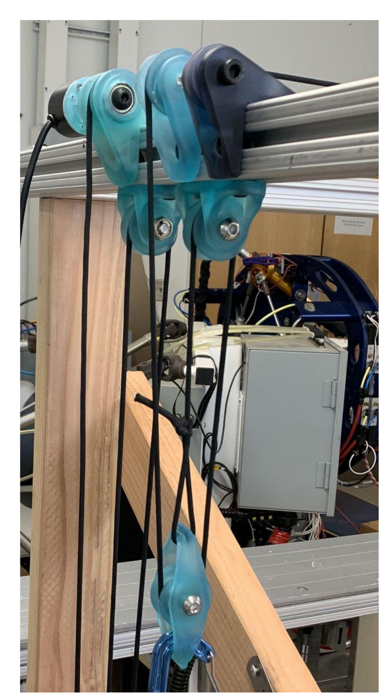

Fig 5. FMM Prototype

Force Multiplication Mechanism Design

Decrease the distance traveled by the spring and linear actuator

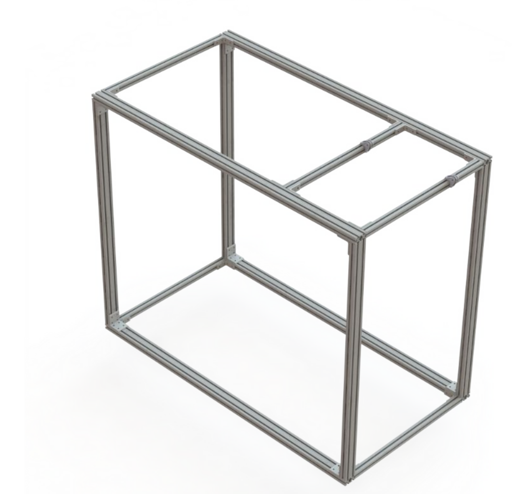

Fig 6. Frame Design

Frame Design-

Use off the shelf parts to achieve quick testing and prototyping

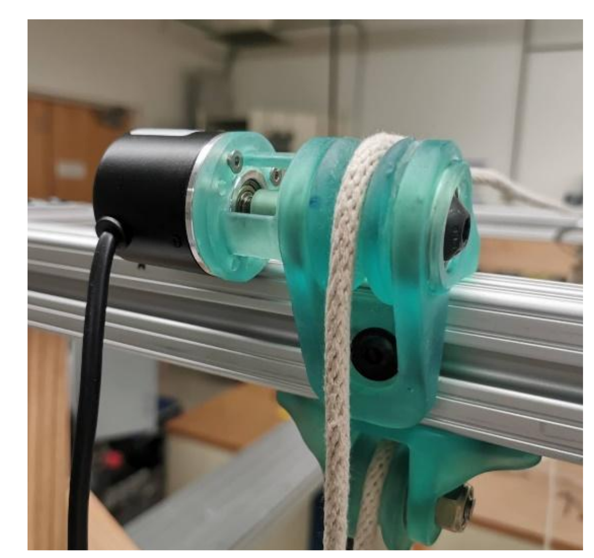

Fig 7. Rotary Encoder Prototype

Rotary Encoder System-

To attach the encoder to the whole system for data collection.

Analysis

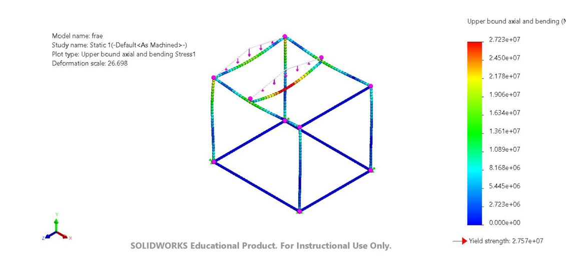

Fig 8. Frame FEA

Finite Element Analysis - Static analysis of the frame showed the design has a safety factor greater than 2

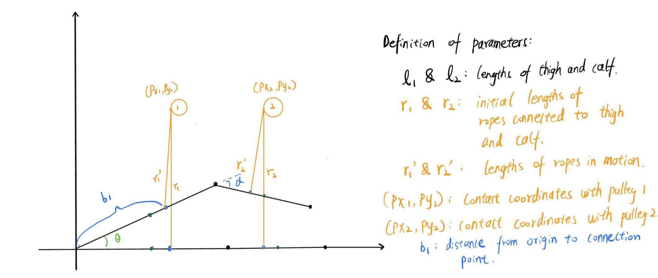

Fig 9. Post Processing Derivation

Leg Motion Analysis- Analysis on the relationship between cable length to leg position was done to create an accurate post processing algorithm

Performance

- Airstep meets requirements
  - supports patients legs
  - is durable and safe
  - Takes accurate measurements
  - Low cost
  - Small enough for standard doorway
- Linear actuator is able to create a constant force
- However, current linear actuator is too slow

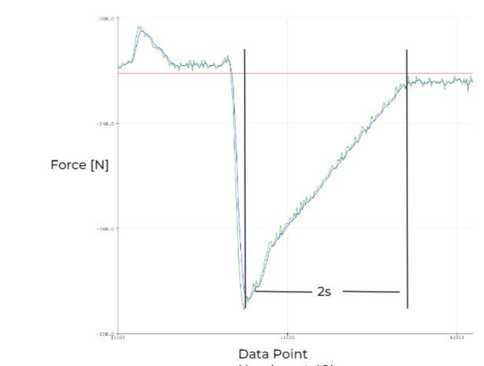

Fig 10. SEA Input Step Response

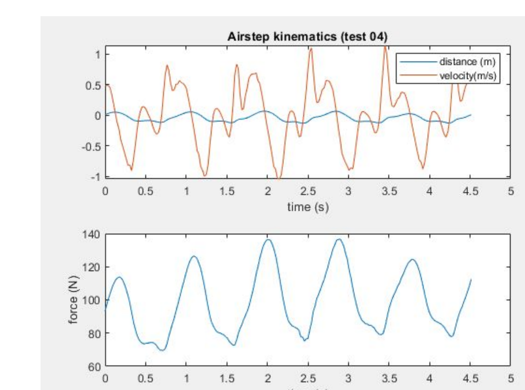

Fig 11. Distance, Velocity and Force vs Time

Future Improvements

Active System

- Faster actuation system coupled with controllers and filters to constantly adapt to the motion of the leg

Leg Cradle

- Functioning leg cradle that is adjustable for height and weight
- Equipped with sensors to measure leg flexion and motion

Sensors

- Additional sensors to be considered such as optical sensors or potentiometers to measure distance and leg flexion

Frame

- Using aluminum extrusions for the entire frame, along with wheels.
- Manufactured pulleys and stronger cord for the system as well

Acknowledgements- The team would like to thank the following:

Dr. David Reinkensmeyer and **Chris Johnson** for their advice and knowledge in regards to the project and allowing us access to the biomechatronics lab.

References-

[1]. Dr. Reggie Edgerton. Accessed Oct 7, 2022. [mp4 snapshot]