Preventative Care Knee Exoskeleton

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Abstract

The increasing aging population frequently suffers from knee joint degeneration, with 6 million people over 65 showing signs of osteoarthritis in that region [1]. This demographic has limited access to preventative injury solutions due to the high costs of medical devices, thus impacting range of motion, independence, and safety [2]. Typically, assistive exoskeletons to combat these problems are designed for a general population and then fit for each patient. In response, this project aimed to develop a low cost, customizable assistive knee exoskeleton for increased quality of life. The device includes a motor which provides assistance in walking. Testing showed that there is a minimal amount of change of gait when a healthy subject walks with the brace. This shows promise for assisting real patients with osteoarthritis.

Objectives

- To apply user centered design principles for the aging population to increase comfort and independence.
- To actively facilitate knee flexion and extension.
- To use image processing and 3D modeling software to generate and manufacture a customized orthotic.
- To utilize gait analysis for proof of concept, safety needs and functionality requirements.

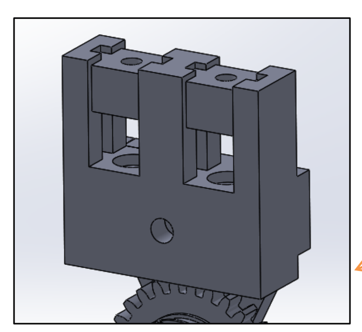
Design

Force Unloading Mechanism

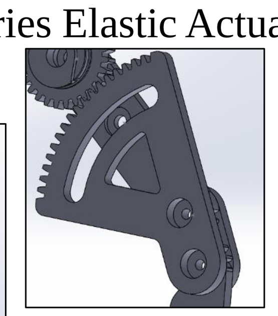
- Series Elastic Actuator allows the motor to move while preventing injury to the user.
- Capstan drive allows for a large gear ratio while keeping the total footprint of the device small.
- Pinion gear of the capstan device also functions as the SEA pulley for an additional gear reduction.
- 3-linkage design allows for the capstan drive to only turn 60˚ for the full 120˚ movement at the leg.
- Custom parts based on a 3D scan of the user allows the device to match the leg profile and stay firmly in place.

Soft Mechanism

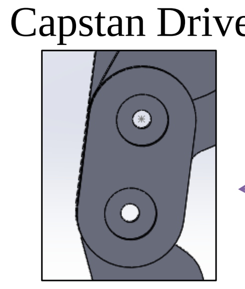
- Under lining designed to promote comfort within the device.
- Anti-microbial property of Nylon material prevents fungal infections from sweat build up.
- Garter design made to limit bending over.
- Velcro closures to ensure adjustability as the body changes.



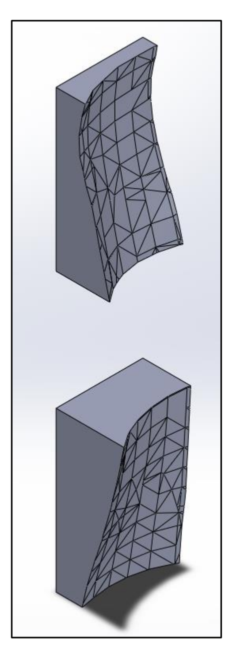
Series Elastic Actuator



Capstan Drive



Multiplier Link



Leg Profile Pieces

1 Control Hardware 2 Bowden Cable/ SEA Transmission 3 Capstan Drive 4 Leg Support Attachment

References

[1] "Arthritis By The Numbers", *Arthritis.org*, 2019. [Online]. Available: https://www.arthritis.org/Documents/Sections/About-Arthritis/arthritis-facts-stats-figures.pdf.

[2] [2]B. Rupal, S. Rafique, A. Singla, E. Singla, M. Isaksson and G. Virk, "Lower-limb exoskeletons", *International Journal of Advanced Robotic Systems*, vol. 14, no. 6, p. 172988141774355, 2017. Available: 10.1177/1729881417743554.

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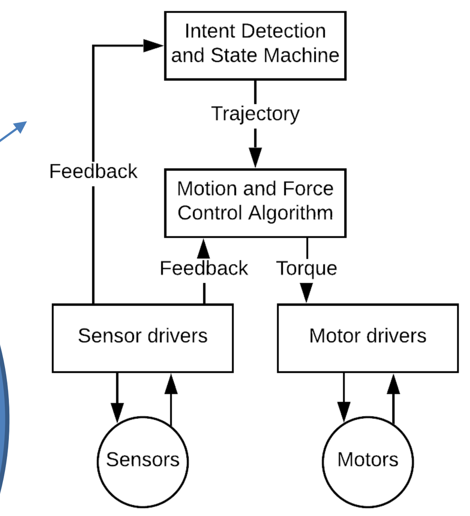
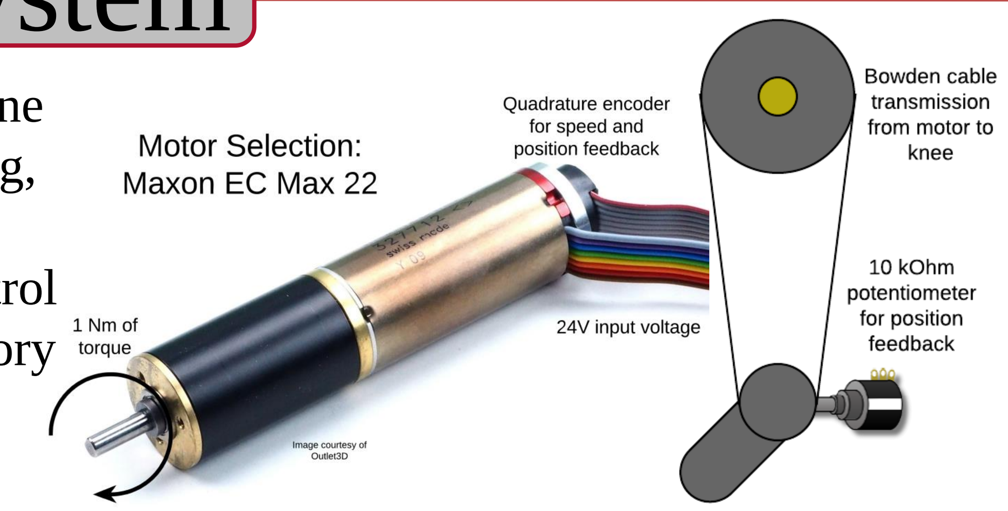
Control System

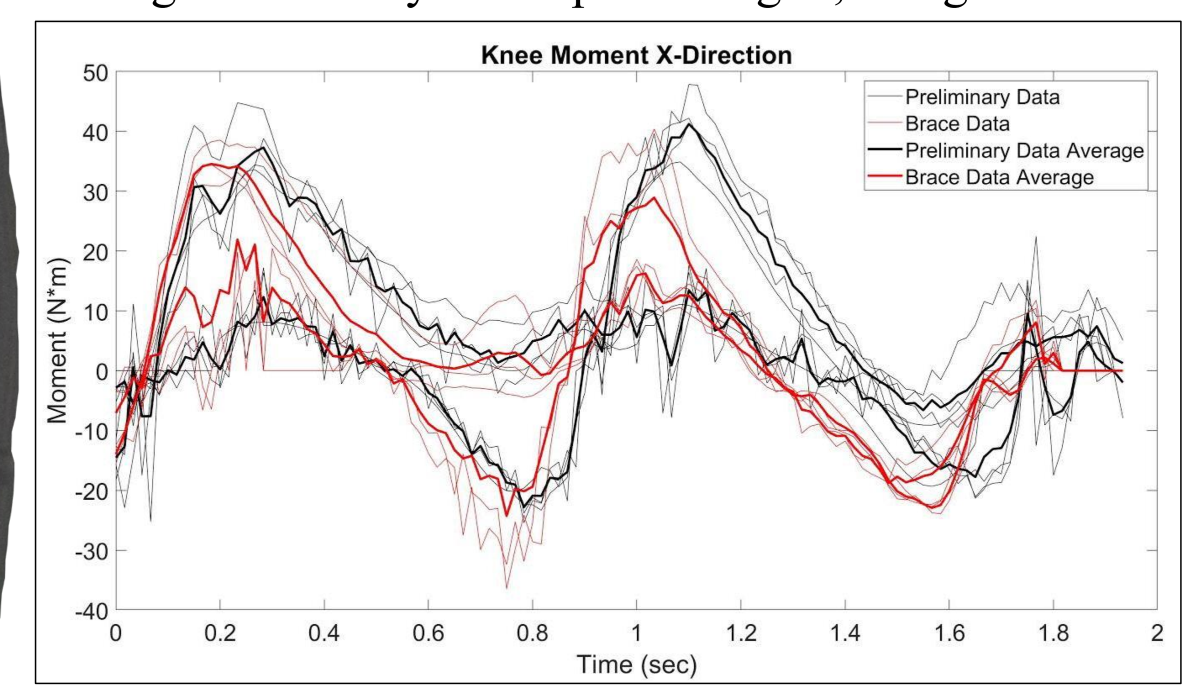


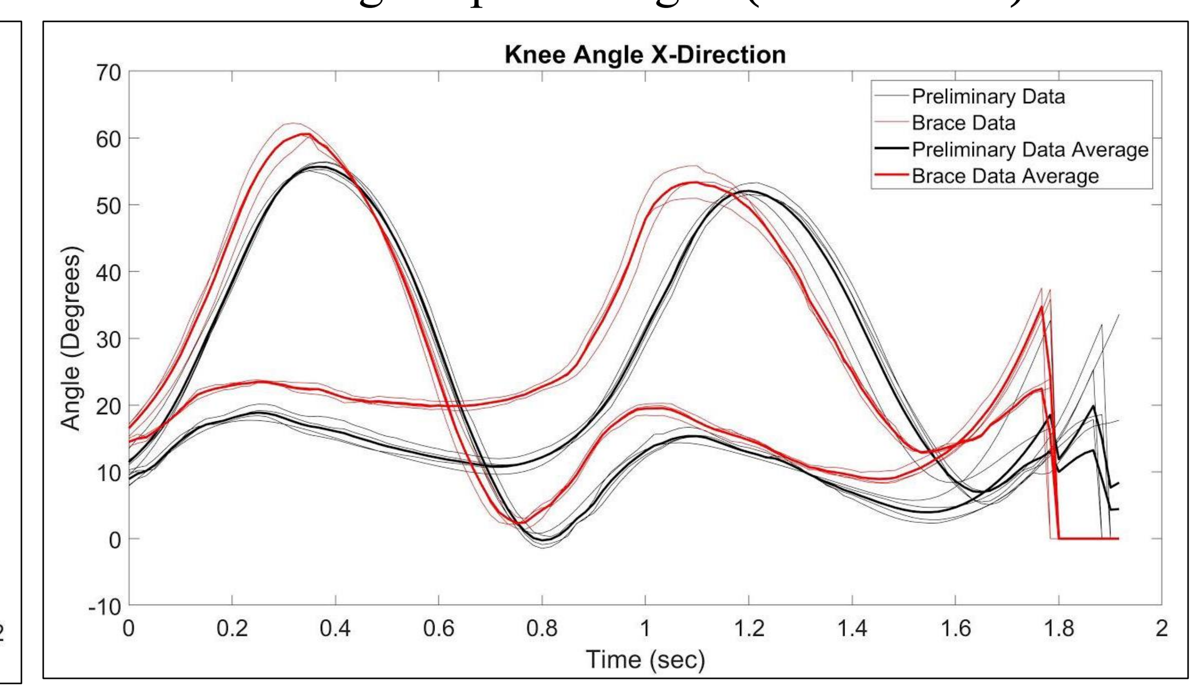
Based on feedback, the state machine determines user intent (start walking, stop). During walking, the gait trajectory is sent to the motion control algorithm. Closed-loop PID trajectory control is used to move the motor through the gait cycle.



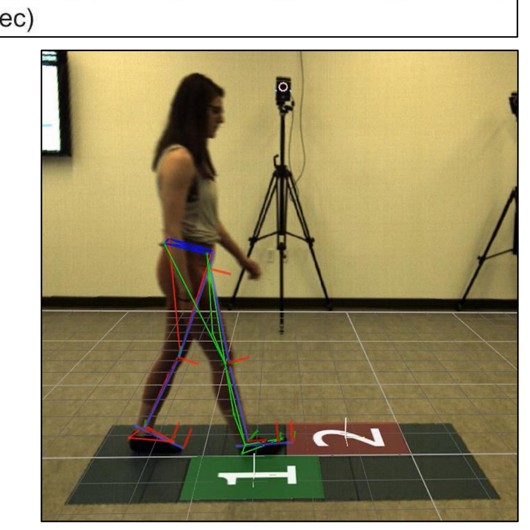
Results

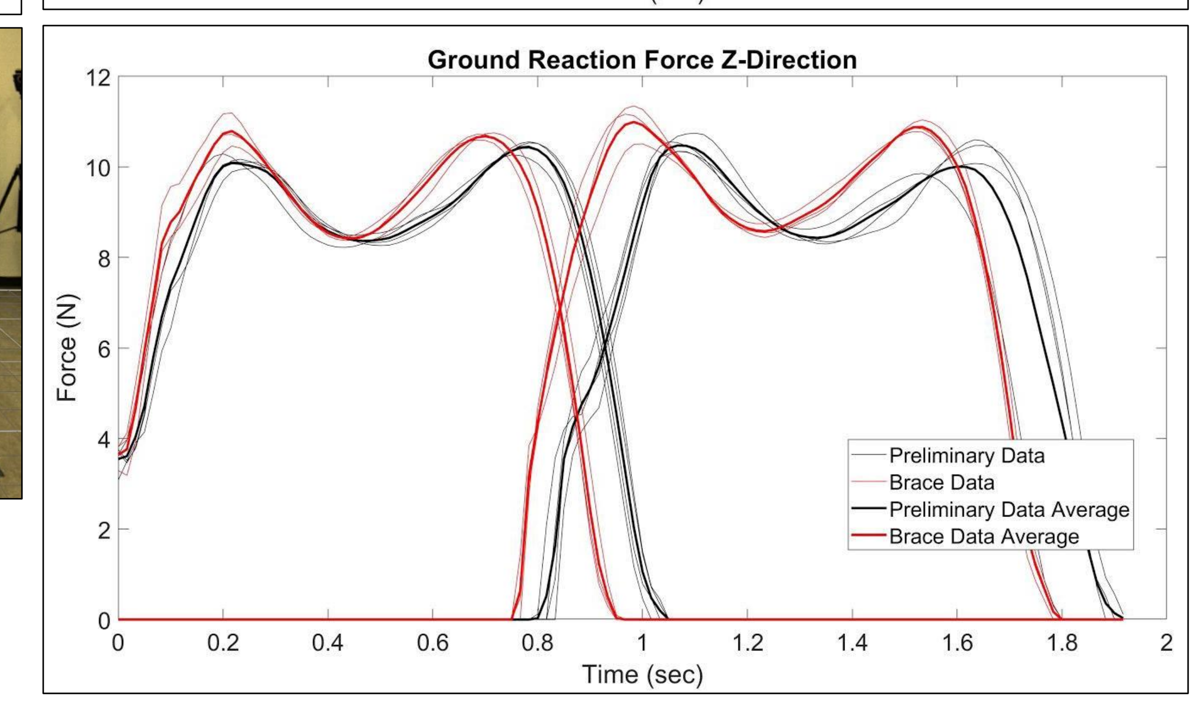
Preliminary gait data using the Vicon system provided the team with important information on the precise correctional forces needed, how the knee can be modeled as an ellipsoid to calculate the joint center, the angular velocity of the patient's gait, and ground reaction forces during the patient's gait (Bottom Left).





- Knee Angle (Top Right): Increase in knee flexion of the right leg when the subject had the brace on.
- Knee Moment Averages (Top Left): The knee moment averages shifted to the left when wearing the brace, but have similar moment pattern as the preliminary data without the brace.
- Ground Reaction Force (Bottom Right): GRF shifted to left due to shorter steps taken and a shorter gait cycle. Results show a higher force when the subject had the brace on than without the brace. Brace adds 0.15 lbs. to total weight.





Conclusions

The device created for this project did not inhibit the gait cycle of a healthy patient. This shows that it has the potential for correcting the gait of an osteoarthritic patient. Future work includes further development of the testing/validation of the device and software. EMG data would allow the group to see what muscles are working during the gait cycle and how much they are working with and without the device. Once the motor control and brace design has been iterated, to where the device works on a normal patient, the next step would be to test on osteoarthritic patients. This would validate the design as successful in aiding with activities of daily living, therefore increasing quality of life in an affordable manner.