Development of a modular actuator for Hip and Ankle joint

Suhrud Parag Joglekar, Master of Science in Robotics and Autonomous Systems (Mechanical and Aerospace Engineering)
Mentor: Dr. Hyunglae Lee, Associate Professor
School for Engineering Matter, Transport and Energy

Research question

Can we devise a modular actuator capable of entraining the human hip joint and offering torque support to the ankle joint for inversion-eversion motion with minimal modifications?

Feasibility of cable driven robot

1. Using for Hip Entrainment:
- In this use case the actuator has a single cable wound on the output pulley using a single slack enabling mechanism Fig[1].
2. Using for Ankle Inversion-Eversion:
- In this use case the actuator has cable wound on the output pulley using two slack enabling mechanisms to maintain constant tension Fig [2].

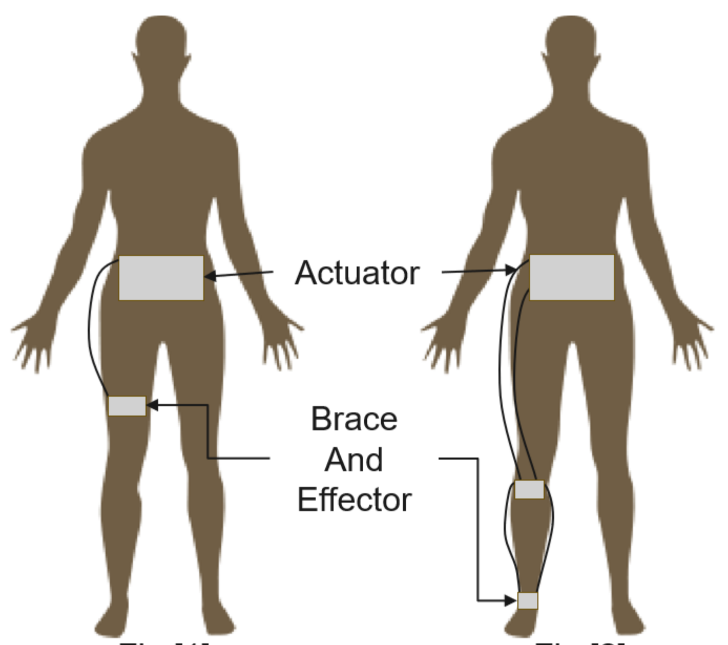
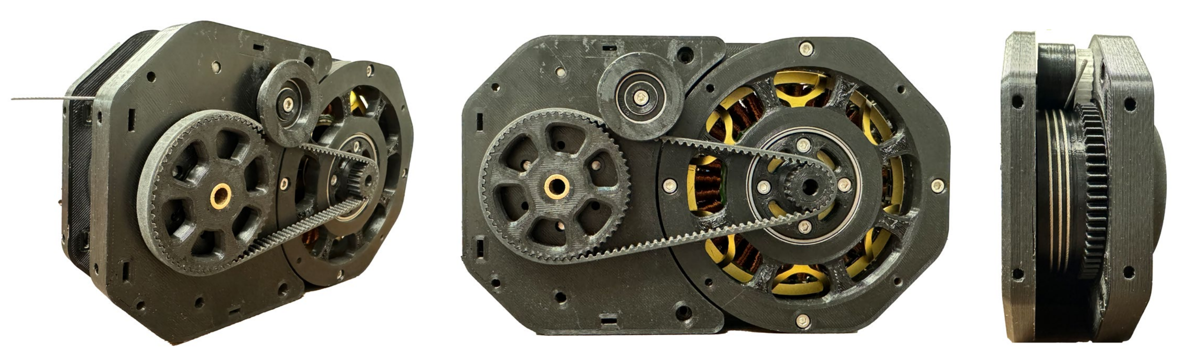
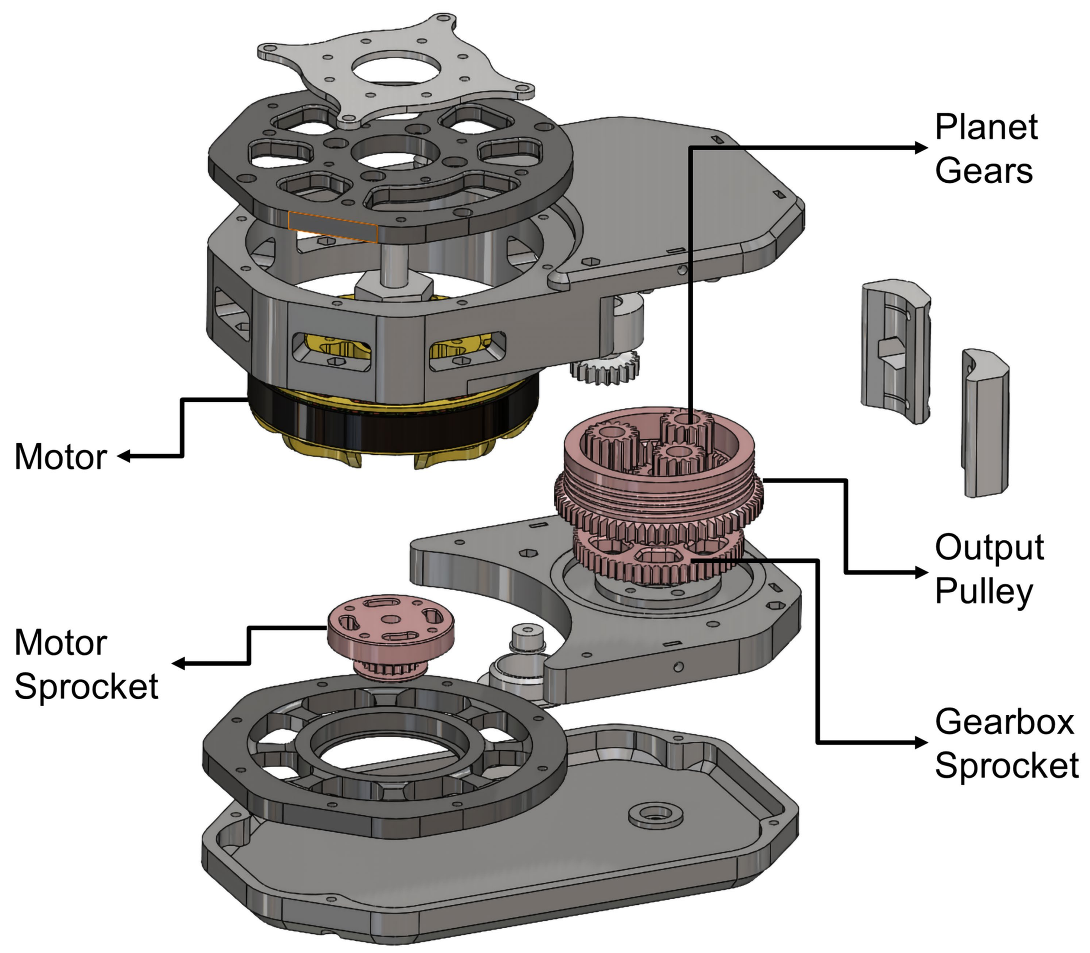


Fig [1] Fig [2]



Actuator Prototype Images

Design of actuator



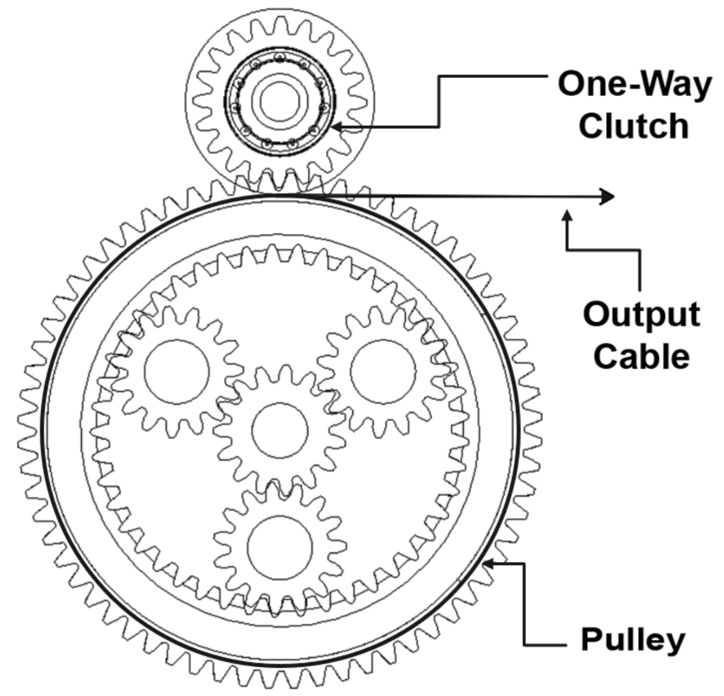
- The actuator incorporates a 90 KV BLDC motor driving a gearbox with a 9:1 overall reduction, comprising a 3:1 belt reduction and a 3:1 planetary gearbox.
- Its weight, including the controller, is a mere 0.85 kg.
- Featuring a 2-stage reduction equally split between a belt drive and a planetary drive.
- With a Slack Enabling Mechanism facilitating precise force control of the cable without external balancing force.
- Capable of generating up to 275 N force or 16 Nm hip torque at 10 A.

Results and Validation

The actuator will be validated using the following tests: (Current Work)

1. **Bandwidth Test** - The Bandwidth Test evaluates how well the actuator responds to different frequencies, ensuring it can maintain accurate positioning and rapid response across various operational demands. It identifies resonance frequencies and performance limitations crucial for dynamic movement control.
2. **Torque-Current Characterization Test** - This test measures the actuator torque output at different current levels, providing insights into its torque generation capabilities and efficiency. It helps determine maximum torque, torque-to-current ratio, and power requirements, vital for optimizing control algorithms and ensuring precise operation.

Slack Enebling Mechanism



The slack enabling mechanism, connected to the output pulley with a 3.2:1 reduction, maintains cable tension during feeding and acts as a smooth bearing during winding.

Future Work

The actuator will be employed to test human hip entrainment and support ankle inversion-eversion motion, potentially reducing sprain injuries.

Acknowledgement

I am extremely grateful to my mentor Dr. Hyunglae Lee for providing the opportunity to work under his guidance. I am equally grateful to Omik Save for his assistance and continuous support. Additional thanks to the MORE committee for funding this research.

MORE
Masters Opportunity for Research in Engineering

ASU Ira A. Fulton Schools of Engineering
Arizona State University