D13: A Wearable Hand Assistive Device

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Introduction

One significant challenge faced by individuals with partial paralysis is the compromised functionality of their hands, which hinders their ability to carry out activities of daily living. A hand assistive device has the potential to improve the lives of such individuals significantly. They would be able to regain independence after sufficient rehabilitation and occupational therapy. The following were the objectives for our device:

1. Ability to generate a force of at least 10 N, as suggested in [1].
2. A soft and compliant device that is relatively lightweight.
3. Offer independent control of different finger compartments.
4. Ability to sense the intention of the user and switch states accordingly.
5. Should provide at least 2 degrees of freedom for the thumb.

Mechanical Module

The proposed underactuated tendon mechanism is presented in Fig. 1. The cable has origins at the proximal end of each phalange and insertions at the middle of each phalange.

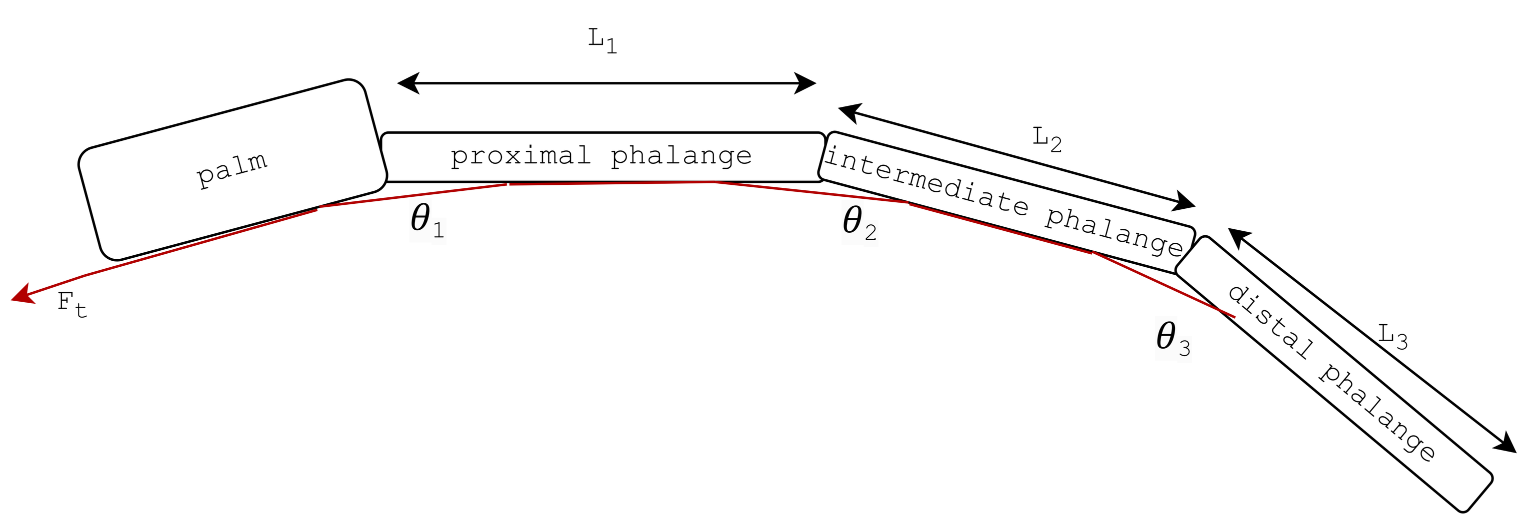
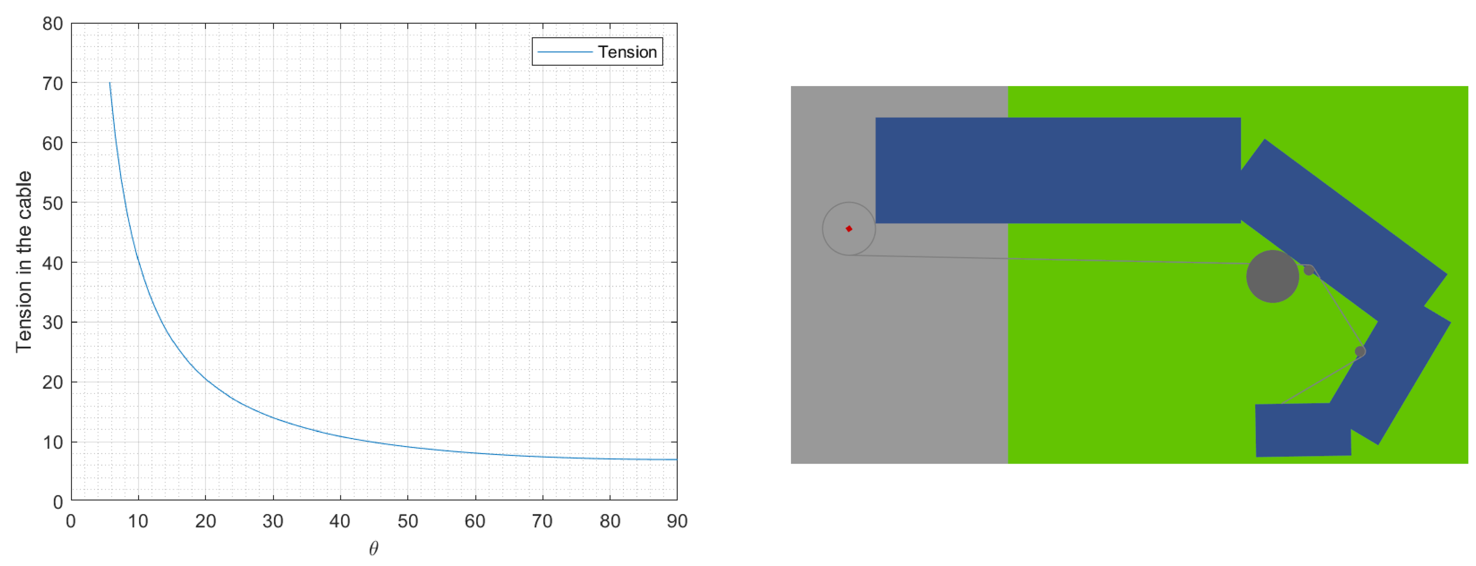


Figure 1. Routing of the cable

Simulation data indicates that the angle of contact between the line of action of tension and the distal phalange is close to $45°$ when the phalange is near full flexion. Fig. 3a shows the relation between F_t and θ, while Fig. 3b shows one possible grasp configuration of the system.



(a) F_t vs θ

(b) Grasp configuration

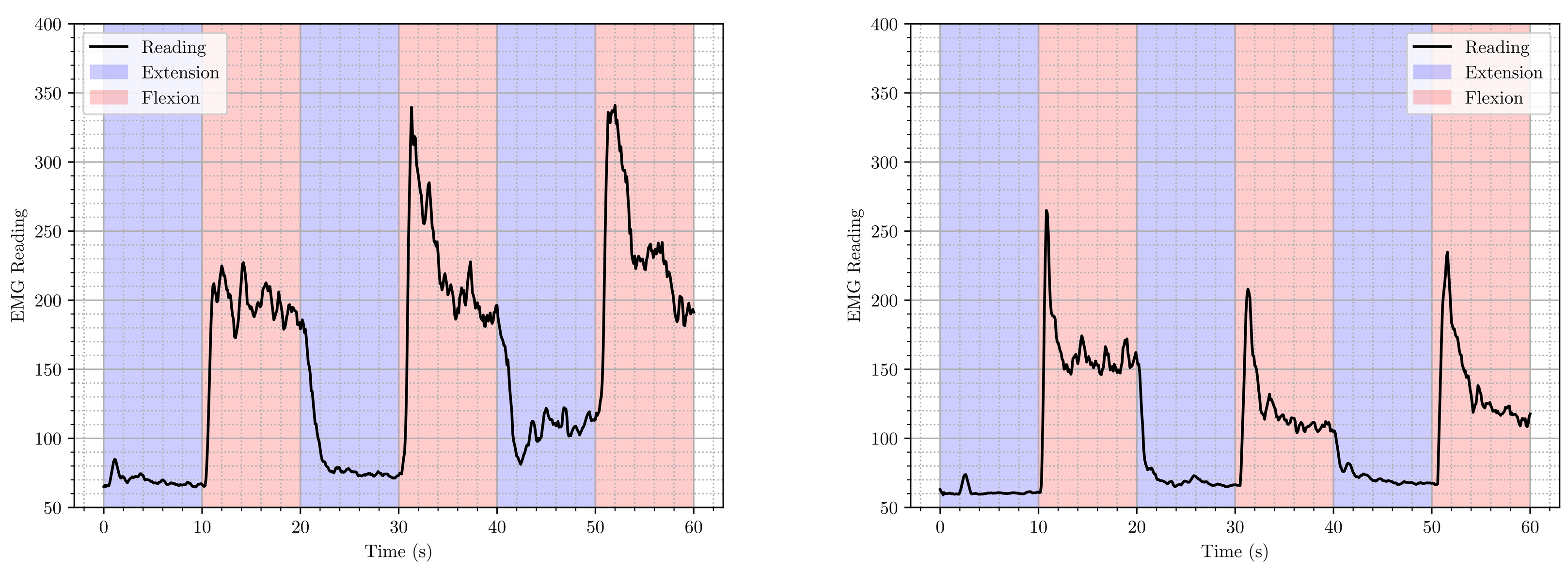
Figure 2. Computing the torque requirements

Based on this result and taking into consideration the weight constraints, we chose the Xcluma Metal TT DC motor. It has a maximum torque rating of 0.8 kg-cm, which corresponds to a maximum tension of 9.8 N.

Intent Detection

Implemented by classifying states using the EMG sensor measurements. The sensors should be placed on the belly of the muscle that contracts during the action. For the flexion and extension of the hand:

1. The *flexor digitorum profundus* and the *flexor digitorum superficialis* muscles located in the anterior forearm.
2. The *extensor digitorum* located in the posterior forearm.



(a) Anterior forearm

(b) Posterior forearm

Figure 3. EMG signal measurements

The device goes to the *flex* state when the anterior measurements go above 150 and goes to the *extend* state when the posterior measurements go above 100.

Electronic Module

High level control:

- **Cylindrical grasp:** In this mode, the thumb is made to carry out retroposition-opposition, and the other 4 fingers are made to carry out flexion-extension.
- **Lateral pinch:** In this mode, the thumb is made to carry out abduction-adduction movements, and the rest of the fingers undergo flexion-extension.

Intermediate control:

The state machine diagram for the device is given in Fig. 4.

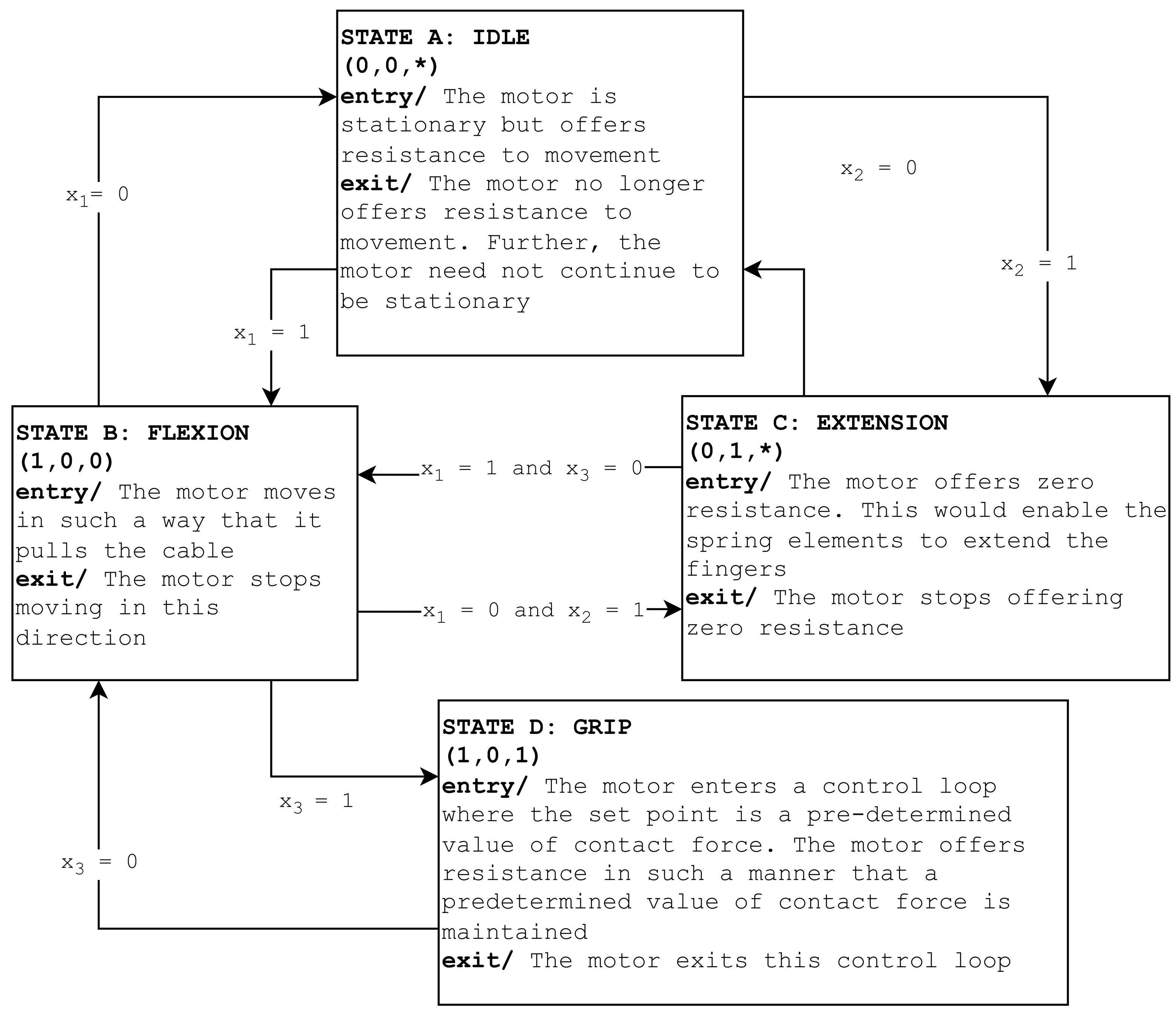


Figure 4. State Machine Diagram

Low level control:

- During the extension and flexion states of the device, the motors run at full speed in the respective direction.
- During the grasp state, the device enters a control loop that ensures a constant pre-defined force is maintained.
- During the idle state, the motors remain stationary.

Results

In this project, a proof of concept prototype of a wearable hand assistive device has been presented. The device consists of 2 layers: a sensor glove with the flex and force sensors and an actuator glove with the cables and the elastic elements, given in Fig. 5. The underactuated mechanism is compliant and is capable of providing a grasping force of 10 N.

(a) Palmar side of the actuation layer

(b) Dorsal side of the actuation layer

(c) Palmar side of the sensor layer

(d) Dorsal side of the sensor layer

Figure 5. The prototype

Future Work

- Firstly, we intend to make the EMG sensor intent detection much more robust by employing a wearable EMG band.
- Then, we aim to work towards finding a more seamless way to incorporate the actuators into the fabric of the device to reduce the bulk of the control system. The usage of micro-motors is one potential avenue to explore.

References

[1] Lucas Gerez, Junan Chen, and Minas Liarokapis.
On the Development of Adaptive, Tendon-Driven, Wearable Exo-Gloves for Grasping Capabilities Enhancement.
IEEE Robotics and Automation Letters, 4(2):422–429, April 2019.