Bionic Knee Orthotic for Patients with Muscular Spasticity

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Background

Cerebral Palsy (CP):

- CP is a group of permanent disorders that affect the development of movement and posture, typically impairing gait [1]
- Hemiplegic gait is a common pattern in patients with CP, due to spasticity, preventing knee flexion and extension
- 41.8% of patients cannot independently walk and need an assistive device [2]

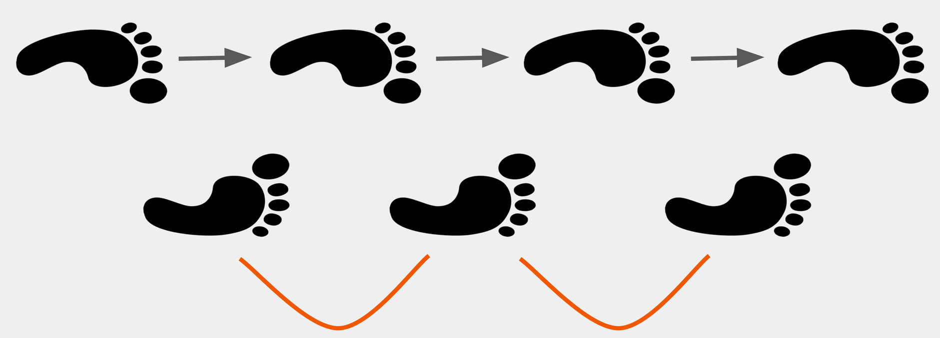


Figure 1: Demonstration of foot movement in hemiplegic gait. This 'swinging' leg motion is due to the inability of CP patients to properly flex and extend their knee during gait.

Needs Statement: CP patients need a way to assist with leg swing movement during gait to independently mobile at home.

Design Criteria

Criteria	Requirement
Portability	Patient needs to independently be able to use device at home
User friendly wearable	Entire device is donned and doffed in less than a minute and weigh less than 20lbs
Compatible with supporting orthotics (AFO)	Fits comfortably and does not impede with AFO device and functionality
Efficient and lightweight power source	Power source is suitable for 30 minutes of light-moderate physical activity and weigh less than 5-10 lbs
Limit joint-angles of extension + flexion	Device will not flex knee more than 135° and will not extend knee less than 2°
Capable of detecting voluntary muscle contraction	Design will include technology to measure muscle activity and filter out dystonia

Standards

ASTM F2808 - 17: Biocompatible materials for brace to skin
ASTM F3109 - 16: Testing and standard parameters for CP walking
ASTM F3474 - 20: Testing parameters and practice for exoskeleton
ASTM F3517 - 21: Testing parameters and practice for orthotic

Prototype

Brainstorming:

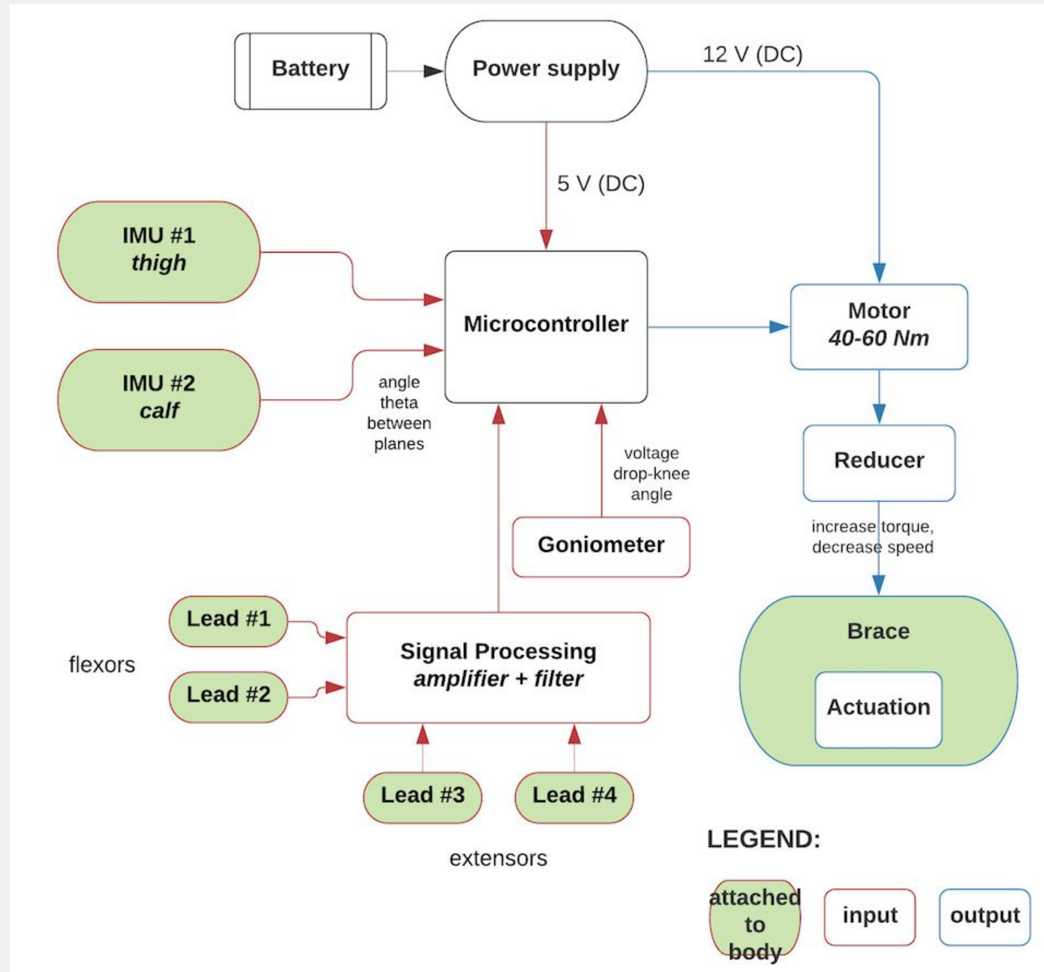


Figure 2. High level overview of prototype design flow

Design of Prototype

- 2 IMUs to detect amount of knee bend
- 4 EMGs to detect muscle contraction, spasticity
- Exoskeleton motor to move brace

Pneumatic vs. Motor Driven Brace

- Pneumatic would be a lighter design but more complex to put together
- Motor would be easier to put together but would be bulkier

Prototype vs Proof of Concept

- Prototyping directly would get prototype done faster but depended on components we were still deciding
- Proof of concept wouldn't use the final components but would allow us to test our idea

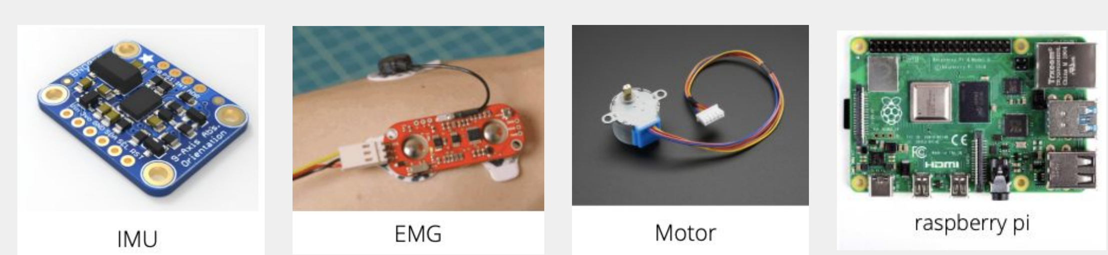
Build vs. Buy Motor

- Building would allow us to customize our motor to specifications but would slow our progress down
- Buying a motor would allow us to continue with prototyping but might not be powerful enough

Prototype V1:

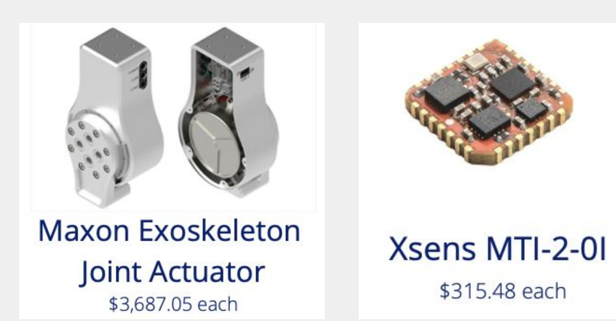
Hardware: Proof of Concept

- IMU: Adafruit BNO055
- EMG: Myoware
- Motor: 28BYJ-48 Stepper
- Raspberry Pi



Hardware: Final

- Maxon Exoskeleton Joint Actuator
- Xsens MTI-2-0I



Mechanics:

Software:

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Prototype File    Component Files
- Prototype.py    - KneeAngleStepper.py
                  - EMG_DataColl.py
                  - IMU_DataColl.py
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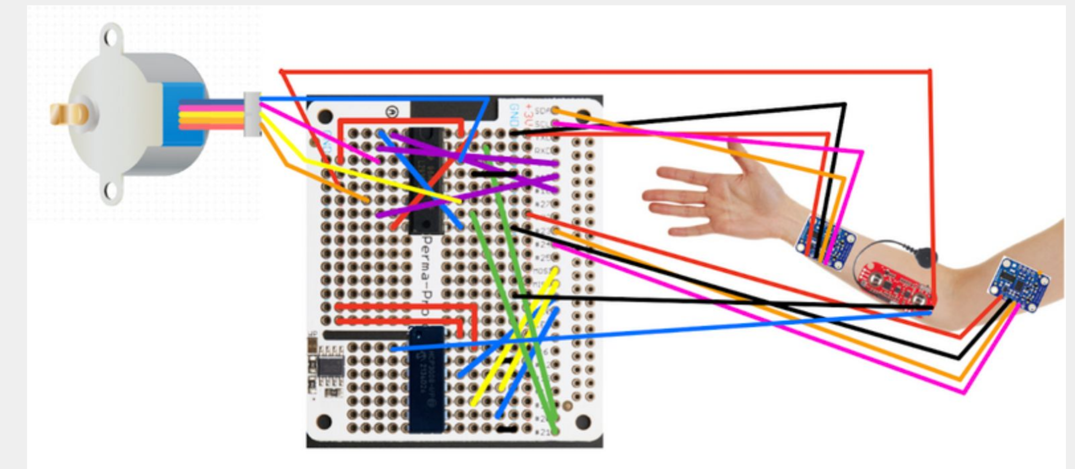
Testing Results

Initial brace design simplified to reduce print time and prototype rapidly

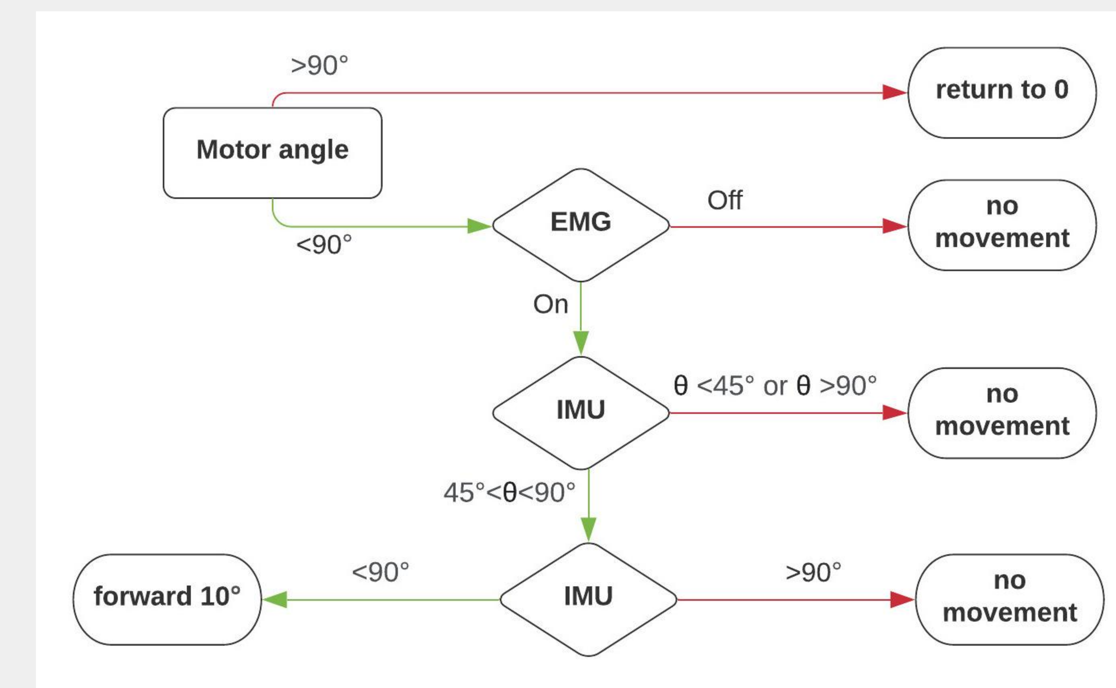
Figure 3. Brace design iterations, from original to simplified



Design tested on arm for ease of access, similar biomechanics

Figure 4. Wiring diagram of all components together

Figure 5. Logic map for proof of concept code file Prototype.py, continuously running in a loop. Components were reduced to 1 EMG and basic stepper motor to get acquainted with parts.



FUTURE DIRECTIONS

Proof of concept → Re-evaluation → Use final components → Revise code and wiring → Revise brace design → Assemble final prototype

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[1] P. Rosenbaum *et al.*, "A report: The definition and classification of cerebral palsy April 2006," *Dev. Med. Child Neurol. Suppl.*, vol. 109, pp. 8–14, Mar. 2007, doi: 10.1111/j.1469-8749.2007.tb12610.x.
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