Force-Based Controller for Myoelectric Prosthesis

Oral Report 3

BME-5
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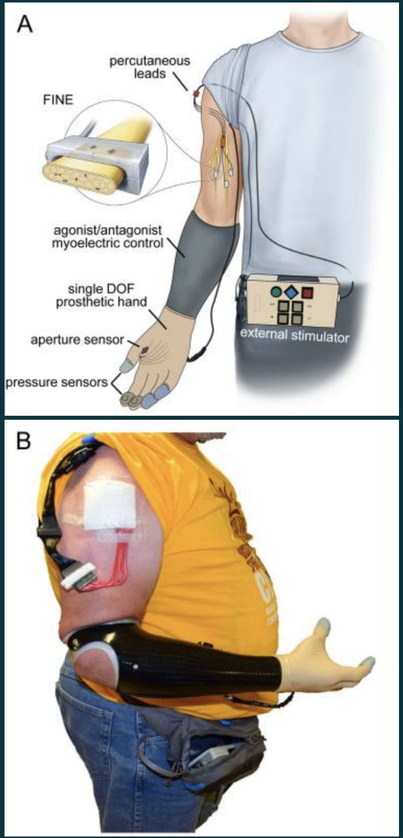
Overview

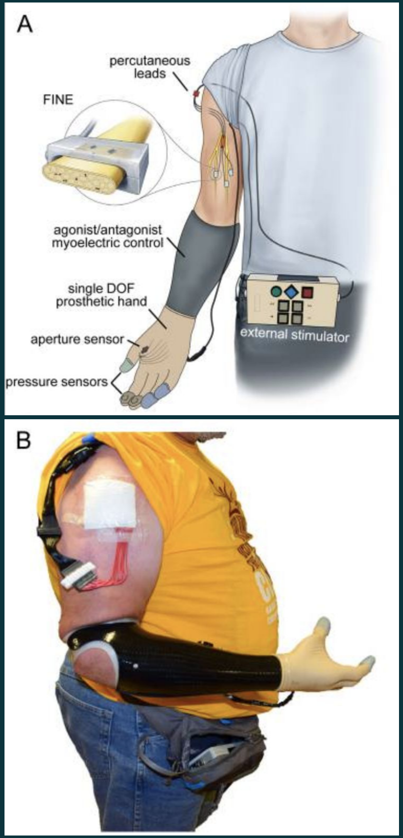
1. Background
2. Our Role
3. Needs Assessment
4. Design Approach
5. Progress Overview
6. Conclusion

Background



Traditional Prosthesis	FINE	Sensory Feedback
Dissatisfaction due to lack of fine motor control and psychosocial repercussions	Flat Interface Nerve Electrodes (FINE) Production of natural tactile sensation without paresthesia	Integration of FINE system with a myoelectric prosthesis allows subjects to "feel" Phase 2: in-home trials launched

Background



Traditional Prosthesis → **FINE** → **Sensory Feedback**

Traditional Prosthesis: Dissatisfaction due to lack of fine motor control and psychosocial repercussions

FINE: Flat Interface Nerve Electrodes (FINE)

Production of natural tactile sensation without paresthesia

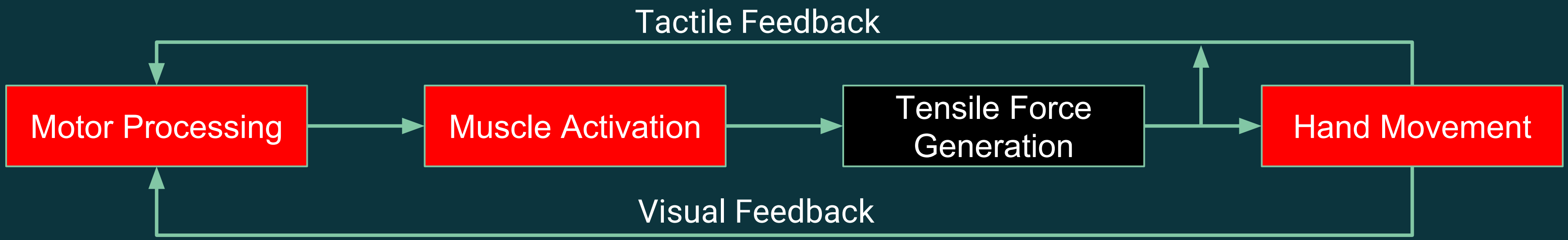
Sensory Feedback: Integration of FINE system with a myoelectric prosthesis allows subjects to “feel”

Phase 2: in-home trials launched

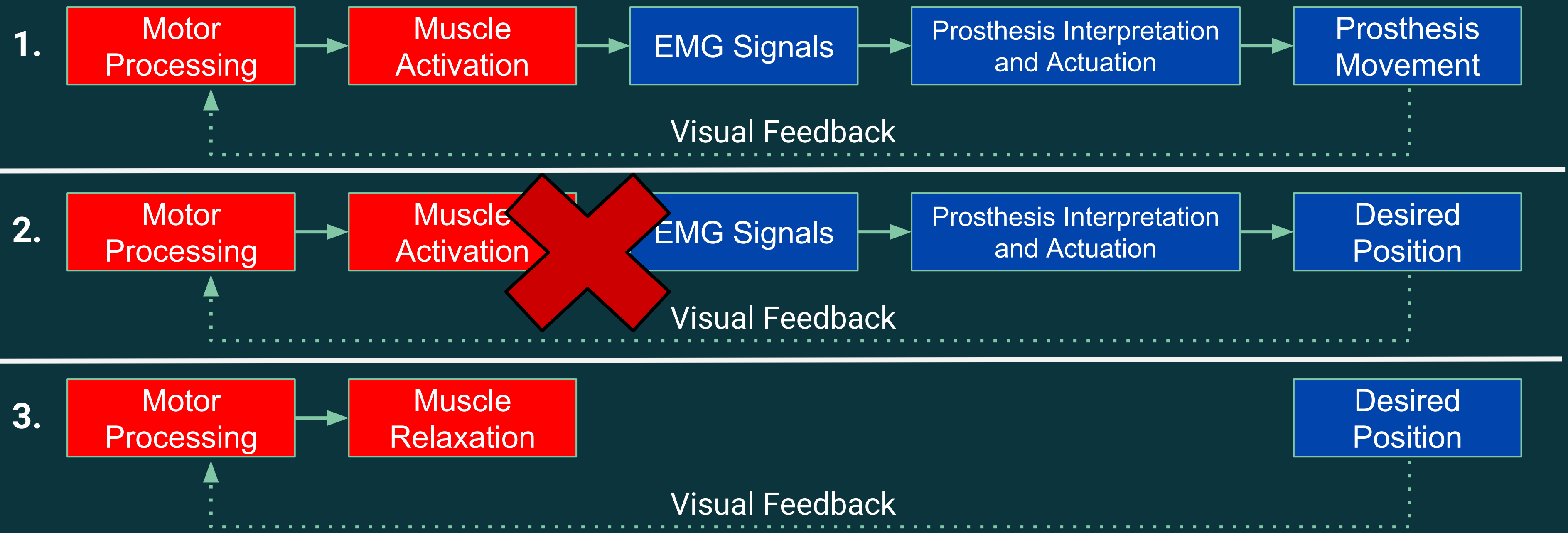
Natural Muscle Control

Key Features:

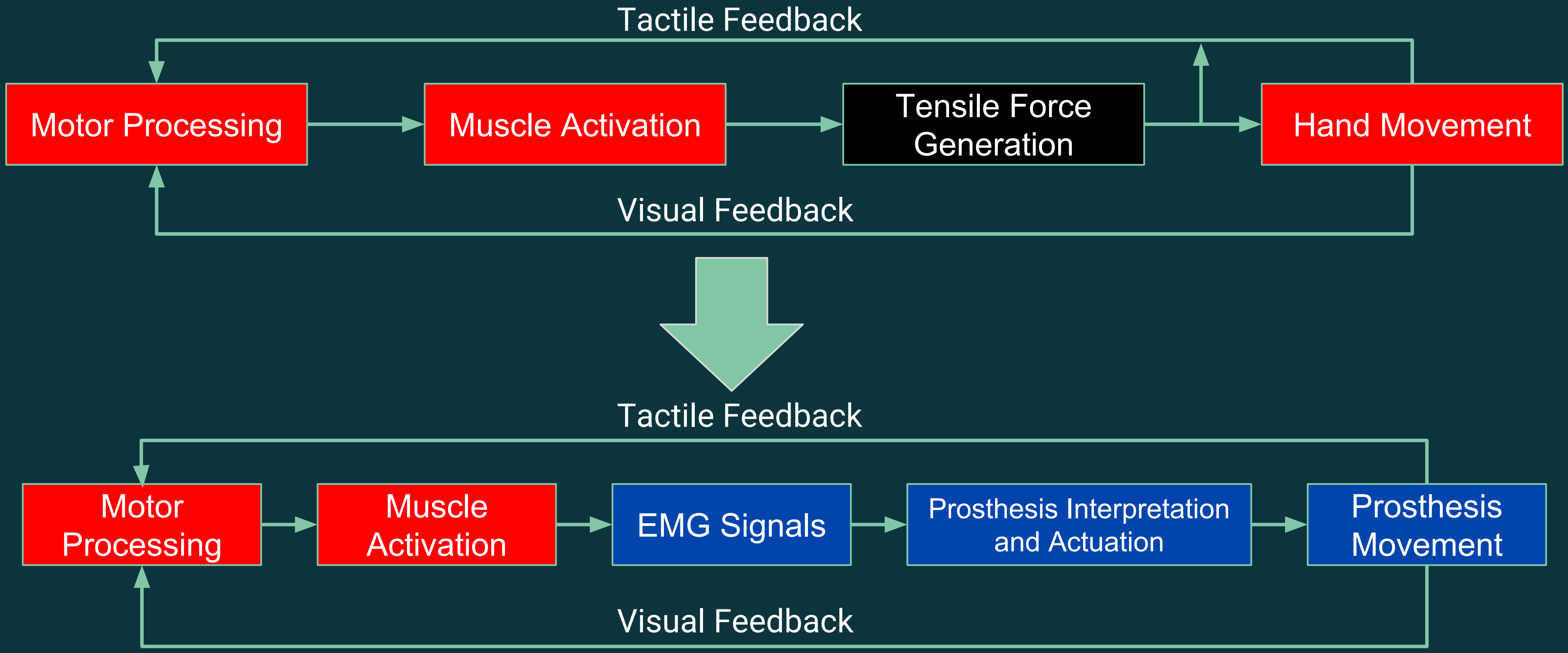
1. Continuous sensory-motor control
2. Tactile + visual afferent feedback
3. Constant motor processing and hand movement coupling



Current Velocity-Based Myoelectric Control

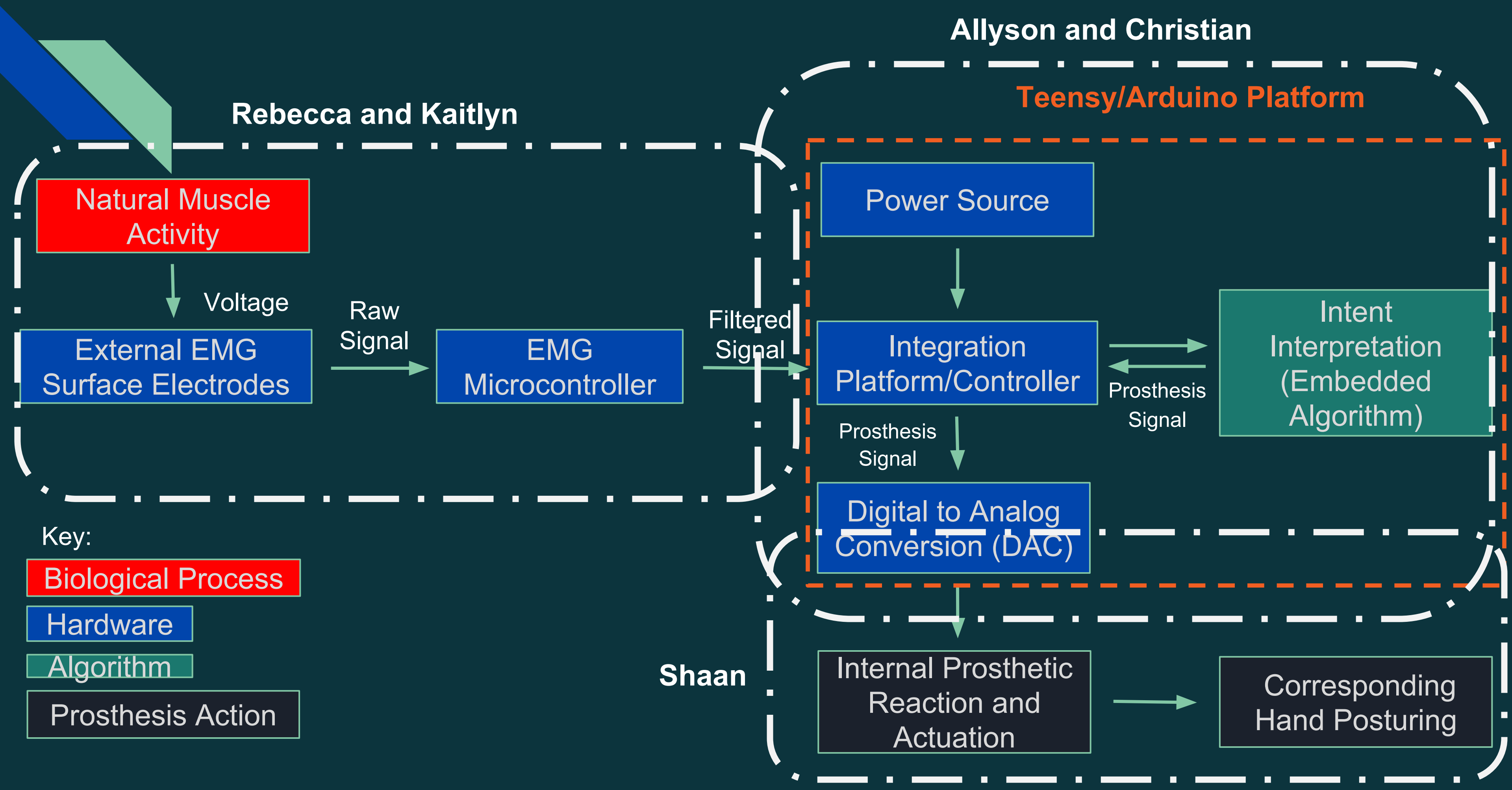


Our Role: Bridging a Gap



Highlights of Needs Assessment

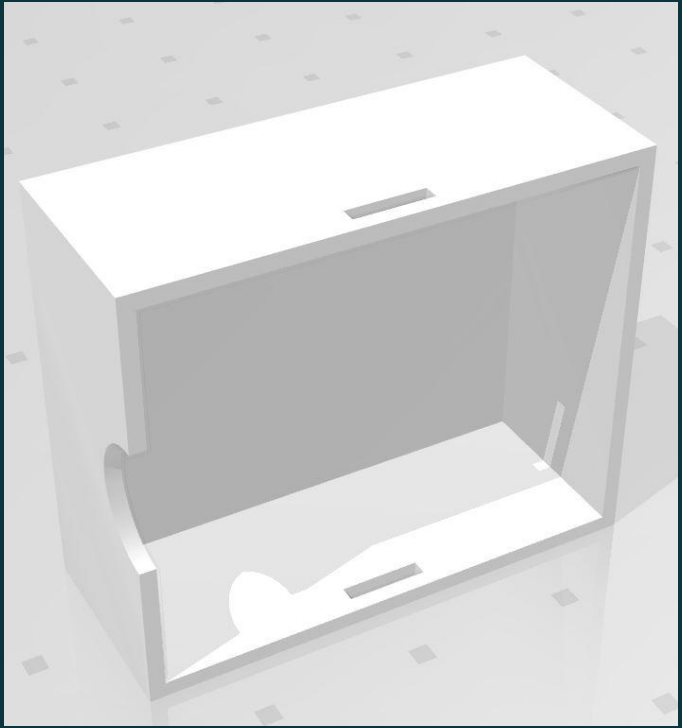
- Adjustable to different patient capabilities
- **More natural control system**
- **Wearable**
- **Durable**
- Safe and Easy to Use
    - Patient Use
    - Prosthetist/Lab Technician parameter manipulation
    - Increased intuitiveness
- **Cost Effective**
- Robust, Quick, Real-Time EMG to prosthesis actuation
- Ultimately: Continued Feedback for Control of Prosthetic hand
- Software and Design Documentation



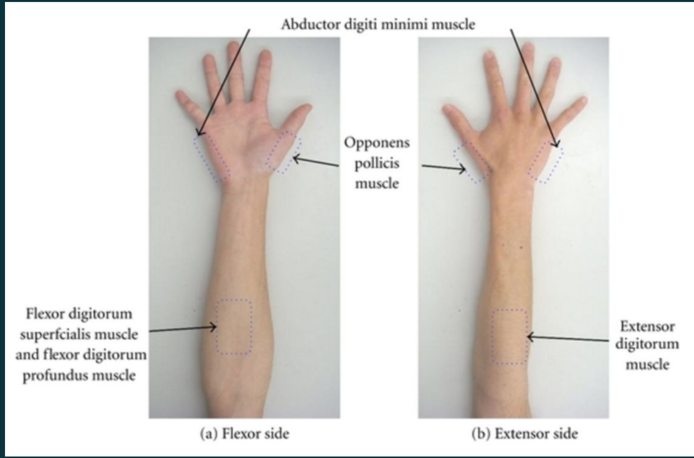
Allyson and Christian
Teensy/Arduino Platform
Rebecca and Kaitlyn
Natural Muscle Activity
Voltage
External EMG Surface Electrodes
Raw Signal
EMG Microcontroller
Filtered Signal
Power Source
Integration Platform/Controller
Intent Interpretation (Embedded Algorithm)
Prosthesis Signal
Prosthesis Signal
Digital to Analog Conversion (DAC)
Shaan
Internal Prosthetic Reaction and Actuation
Corresponding Hand Posturing
Key:
Biological Process
Hardware
Algorithm
Prosthesis Action

Wearability/Durability

- Watch-like attachment to socket
- Protection of wiring and board with cage-like development
    - First Iteration
- Adjustability achieved with strap
- Cardboard Prototype



EMG Acquisition



- Phantom testing designed with human subject
  - Motion will be limited where appropriate for correct signal acquisition
  - Flex and extend wrist to maximize muscle activation
  - Test all team members to find signal with best SNR and highest consistency
- Surface electrodes used for testing
  - Two on extensor digitorum, two on flexor digitorum, ground on either wrist or elbow
  - 3-lead EMG used with bioamplifier

Hardware: Prosthesis

Ottobock Transcarpal Hand (8E44)

- Variable grip speed (force)
- Motor operates using PWM
- Issue: motor not moving with EMG input
    - Gain adjustments
    - Mechanical isolation

https://professionals.ottobockus.com/Prosthetics/Upper-Limb-Prosthetics/Myo-Hands-and-Components/Myo-Terminal-Devices/Transcarpal-Hand-DMC-plus/p/8E44~56-R8%201~24

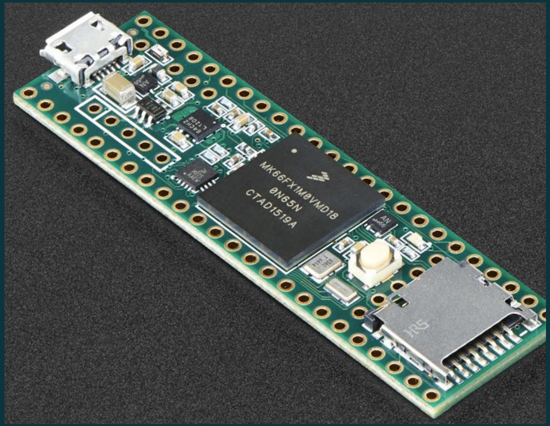
Ottobock Updates

- Made two points of contact at Ottobock
- Learned more history about the device
- Sending prosthesis to Ottobock
    - May or may not charge, figuring out details upon assessment
    - Nominal fee: will look into product being serviced
    - Expensive: Will look into other servos and motors for proof of concept

https://professionals.ottobockus.com/Prosthetics/Upper-Limb-Prosthetics/Myo-Hands-and-Components/Myo-Terminal-Devices/Transcarpal-Hand-DMC-plus/p/8E44~56-R8%201~24

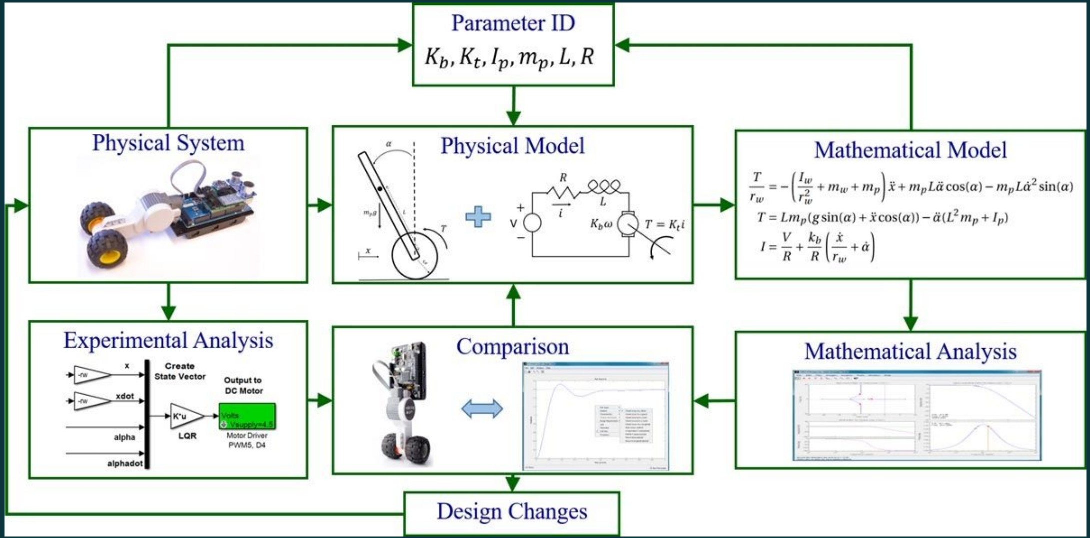
Hardware: External Processing

- Hardware Purchased:
  - Teensy Development Boards
  - Myoware Sensors
  - Battery Pack
- Arduino Compatible Teensy Coded directly into Matlab
  - Coder Familiarity
  - Easy visualisation of data outputs/inputs

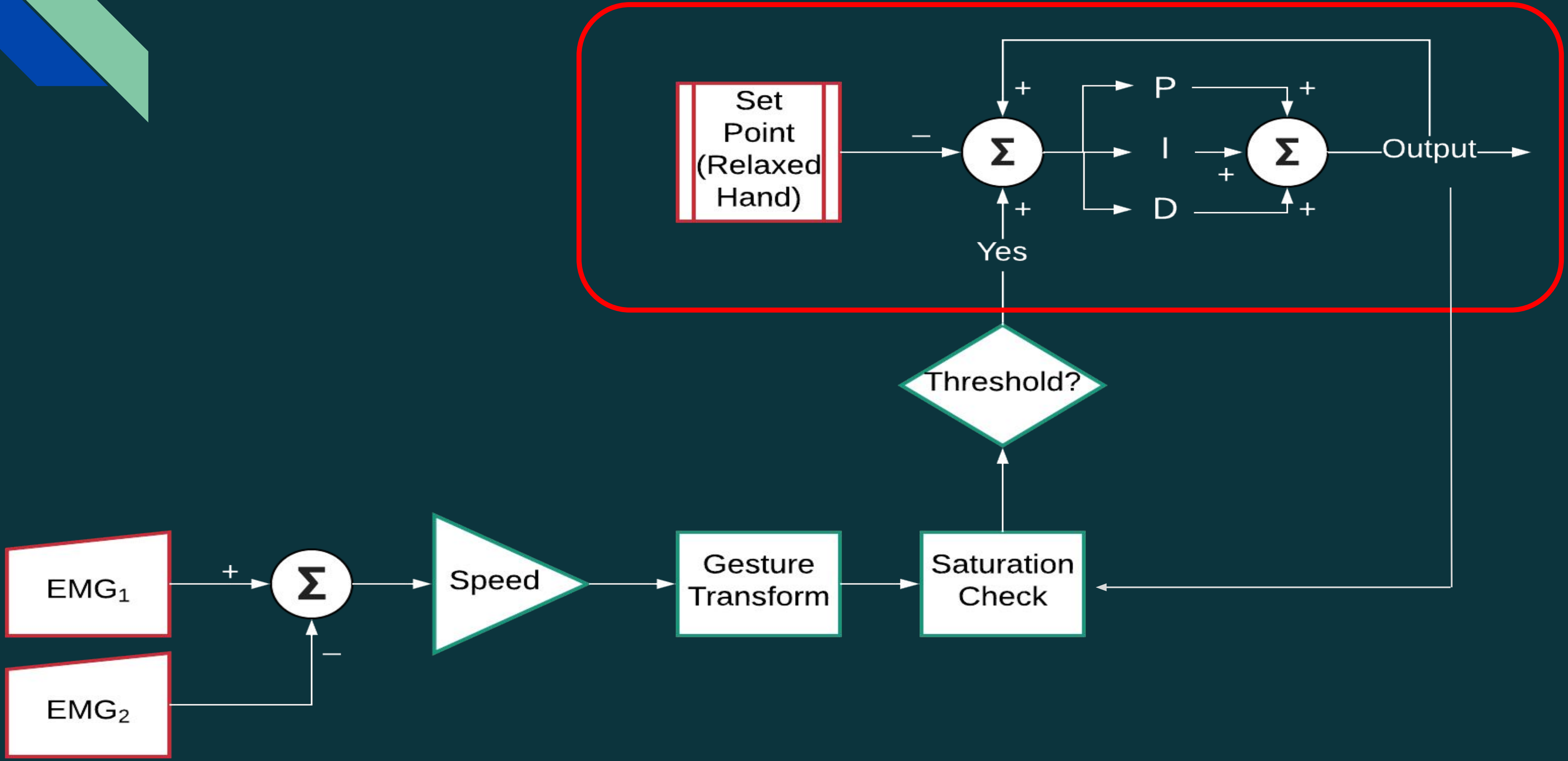


Software and Algorithm Dev

- Version Control
  - Git/Github
- Differential and PID
- Challenges
  - Robust
  - Real-time
  - Isolated
  - Efficient

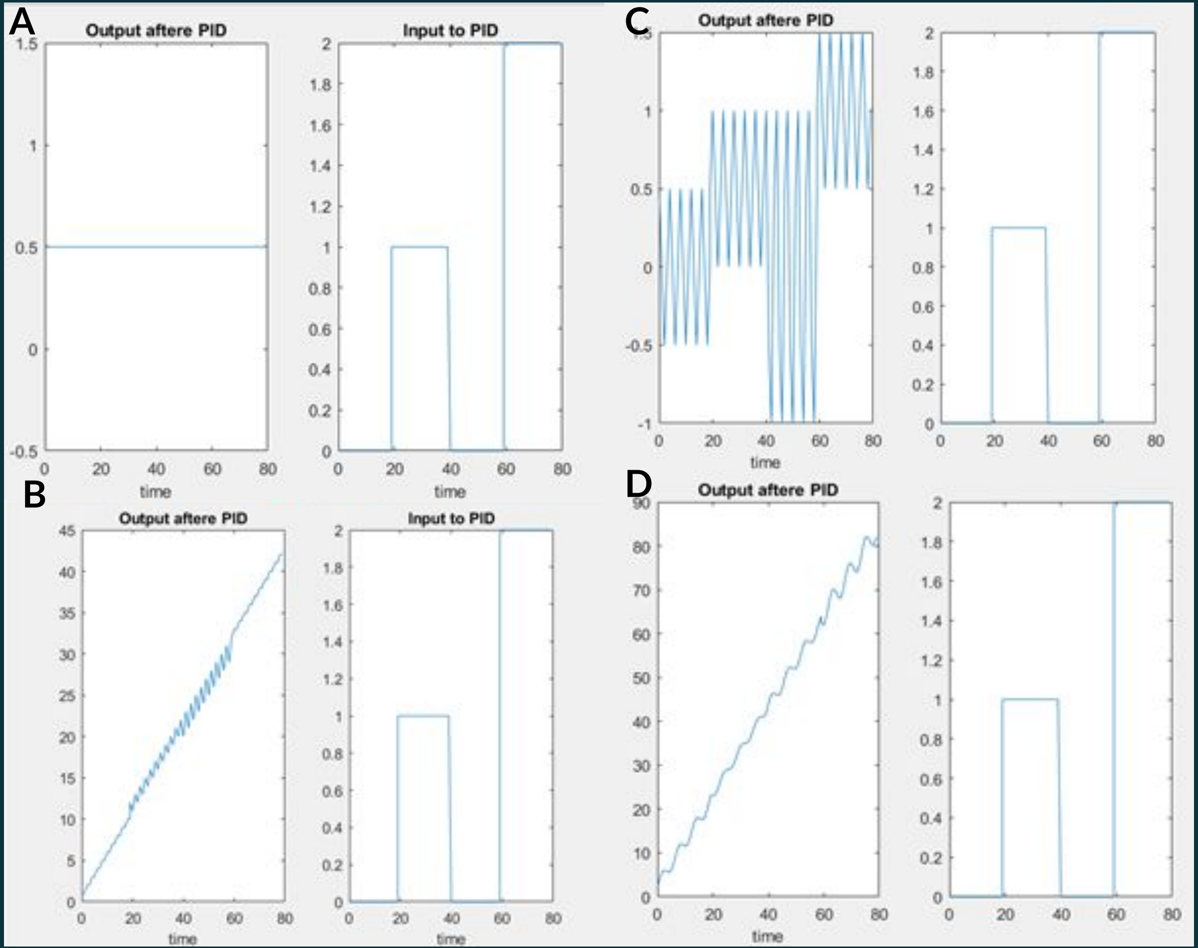


Novel Control System Scheme



Initial PID Iteration: Behavior

- Defined set point
- Varied Integrand, Proportional, and Differential Control
- Varied Inputs



Current and Anticipated Progress

Define the Problem	Needs Assessment	Generate and Evaluate Solutions	Make and Test Model	Improve Design	Design Day

What Questions Do You Have?

References

Slide 3,4 Figure A and B: Graczyk, Emily L et al. “Home Use of a Neural-connected Sensory Prosthesis Provides the Functional and Psychosocial Experience of Having a Hand Again” Scientific reports vol. 8,1 9866. 29 Jun. 2018, doi:10.1038/s41598-018-26952-x

Slide 10 Figure:
https://www.researchgate.net/figure/The-muscles-related-to-finger-motion-The-muscle-functions-are-as-follows-the-flexor_fig6_258378736

Slide 11 Figure: G. Tsenov, A. H. Zeghbib, F. Palis, N. Shoylev and V. Mladenov, “Neural Networks for Online Classification of Hand and Finger Movements Using Surface EMG signals,” *2006 8th Seminar on Neural Network Applications in Electrical Engineering*, Belgrade, Serbia & Montenegro, 2006, pp. 167-171. doi: 10.1109/NEUREL.2006.341203

Slide 13: Battery Pack: https://www.adafruit.com/product/771?gclid=Cj0KCQiAm5viBRD4ARIsADGUT25Rn_FJLIYKc3t2rLc6H1FHcBdir39XMgxD5oLOFZC8Z59nZjuHMcMaApIDEALw_wcB Teensy Board: https://www.adafruit.com/product/3266 Myoware Sensors: https://www.adafruit.com/product/2699?gclid= Cj0KCQiAm5viBRD4ARIsADGUT26WdiQrva9o_F5tG6X3 -FNKWbrwMby-7y-6VrE-zYzJ9XYoIqbCTy8aAmcB EALw_wcB

Slide 17:
https://www.mathworks.com/company/newsletters/articles/teaching-mechatronics-with-matlab-simulink-and-arduino-hardware.html

Appendix

Needs Assessment: Patient

- Comfortable with no extra adjustments needed for the socket
  - Easily adapted to the patient's already customized socket
- Adjustable for different patients
  - Brand/type of prosthetic
  - Amputation type
  - Muscle capabilities
- Ease of Use
  - Minimal learning curve
- Easily donned and doffed
  - Electrode placement and wearable components should be as broad and simple as possible
  - The user should be able to apply and remove the system by themselves
- Psychological Effect
  - Consider psychological effects of using a removable device

Needs Assessment: Patient

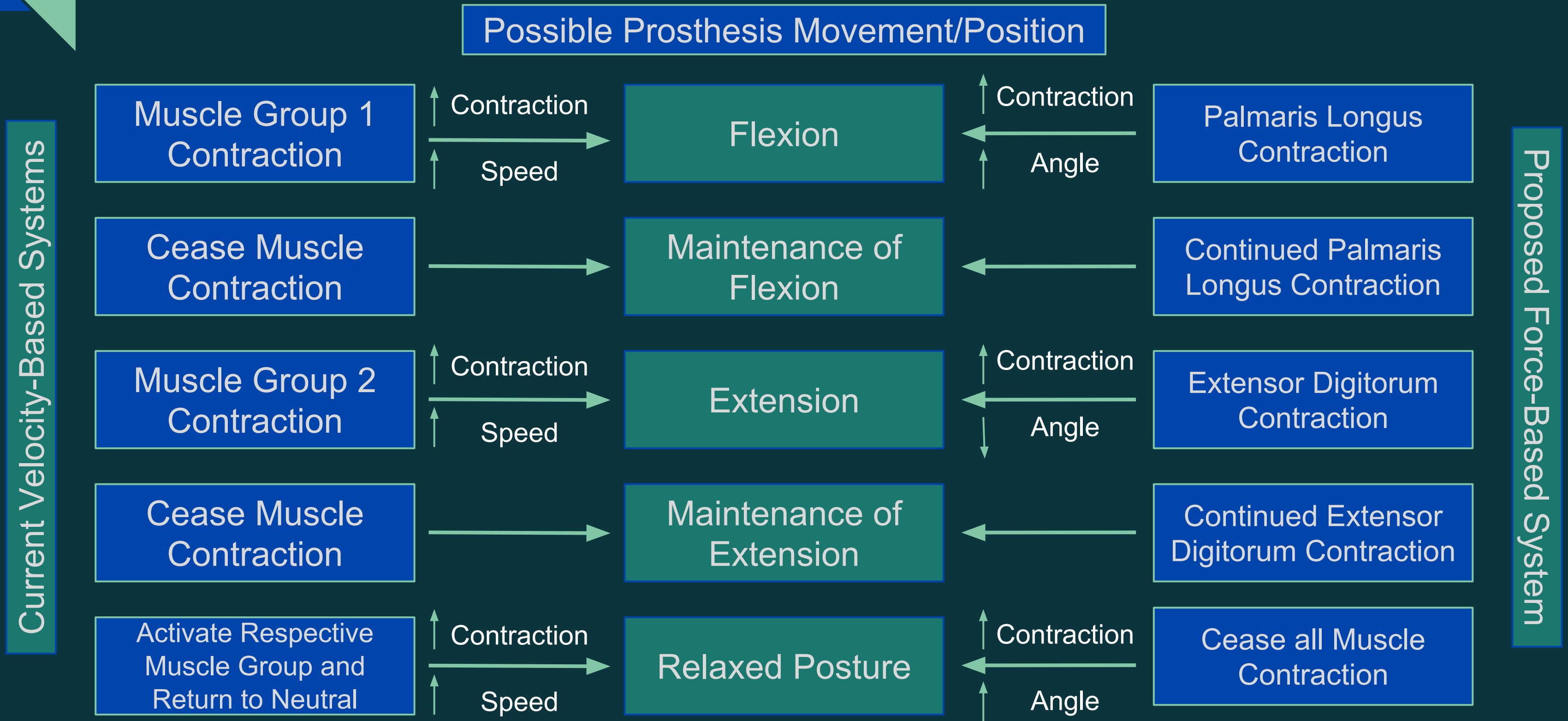
- Wearable
  - Processor either in sleeve above the prosthesis or incorporated into the prosthesis itself
  - Must be tolerable weight for daily use
- Safety
  - Must be designed and built according to quality standards to ensure there are no safety hazards from the mechanical or electrical components
  - Must integrate ability to turn off in emergency situations
- Cost-Effective
  - Components used should be cost-effective to create an inexpensive and easily accessed solution for all users

Needs Assessment: Clinician/Researchers

- Easy access for parameter manipulation
  - If the design requires manual manipulation of electrode setting given amputation or manipulation of muscle activity parameters, a user friendly interface should be created.
- Speed of EMG to prosthesis actuation
  - Should optimize the translation of a captured EMG signal to corresponding prosthesis posture to provide accurate modeling of an intact hand
- Motor control testing functionality
  - Easy integration into lab testing environment with common motor control experiments
- Software and Design Documentation
  - Research Auditing
  - Data and results from the clinical experiments being run can be published
- Clinical Trial Regulations
  - Data output and patient regulations must be considered since device is to be used in clinical trial setting

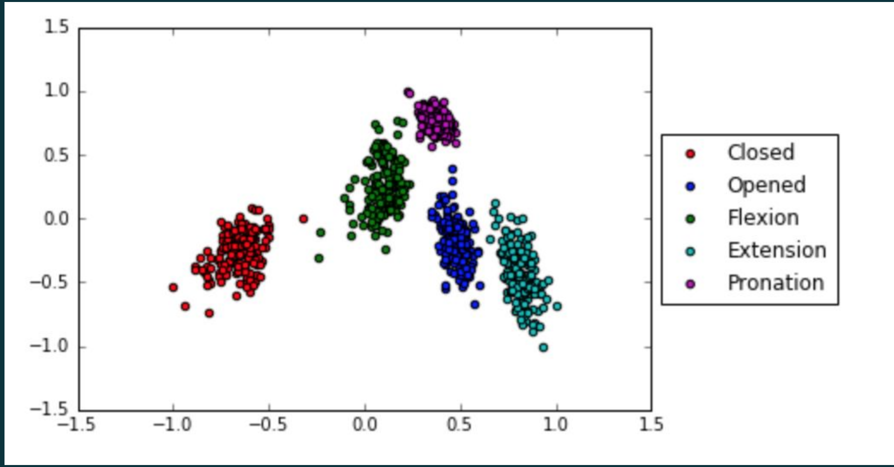
Needs Assessment: System

- Durable
  - Daily use will require durability in different environmental conditions and during general activity
- Integration
  - Must integrate seamlessly with implanted neuromodulated sensory feedback system in users
  - Should minimize noise interference with implanted neuromodulated sensory feedback system and other devices
- Scalable
  - Solution should be applicable to any commercial OttoBock myoelectric prosthesis with minimal modification required
- Biomimetic
  - Natural hand-posturing created by overriding required velocity-based prosthetic inputs


Possible Prosthesis Movement/Position
Current Velocity-Based Systems
Proposed Force-Based System
Muscle Group 1 Contraction
Contraction
Speed
Flexion
Contraction
Angle
Palmaris Longus Contraction
Cease Muscle Contraction
Maintenance of Flexion
Continued Palmaris Longus Contraction
Muscle Group 2 Contraction
Contraction
Speed
Extension
Contraction
Angle
Extensor Digitorum Contraction
Cease Muscle Contraction
Maintenance of Extension
Continued Extensor Digitorum Contraction
Activate Respective Muscle Group and Return to Neutral
Contraction
Speed
Relaxed Posture
Contraction
Angle
Cease all Muscle Contraction

EMG Signal Interpretation

- To do this, Root Mean Square calculates the mean power of the signal, mean absolute value calculates contraction level, and waveform length shows the cumulative length of the waveform



$$RMS_k = \sqrt{\frac{1}{N}\sum_{i=1}^{N} x_i^2}$$

$$MAV_k = \frac{1}{N}\sum_{i=1}^{N} |x_i|$$

$$WL_k = \sum_{i=1}^{N-1} |x_{i+1} - x_i|$$