Force-Based Controller for Myoelectric Prosthesis
Oral Report 5

BME-5
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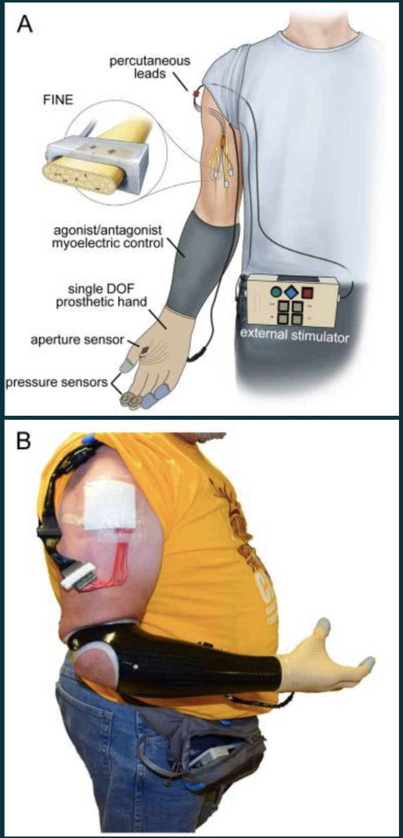
Shaan Ramaprasad, Christian Stano

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

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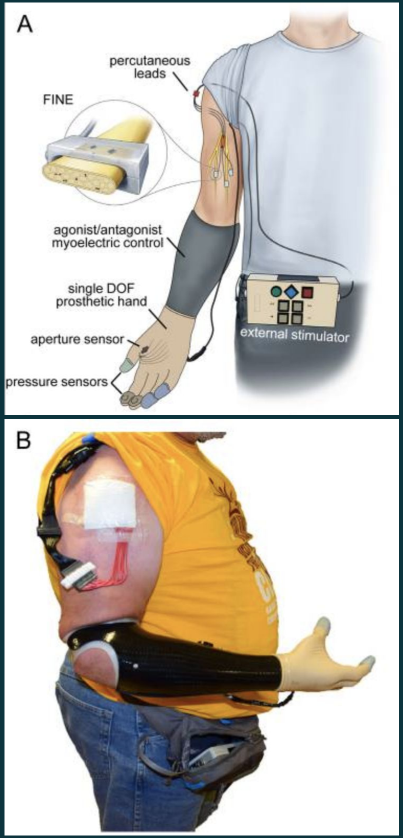

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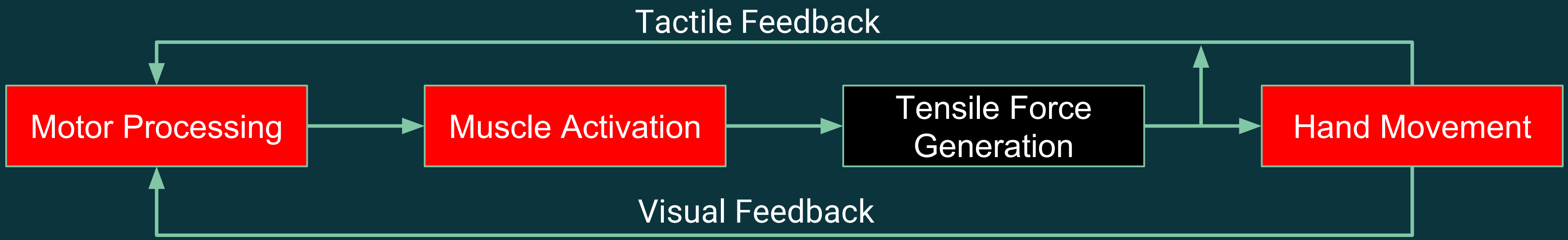
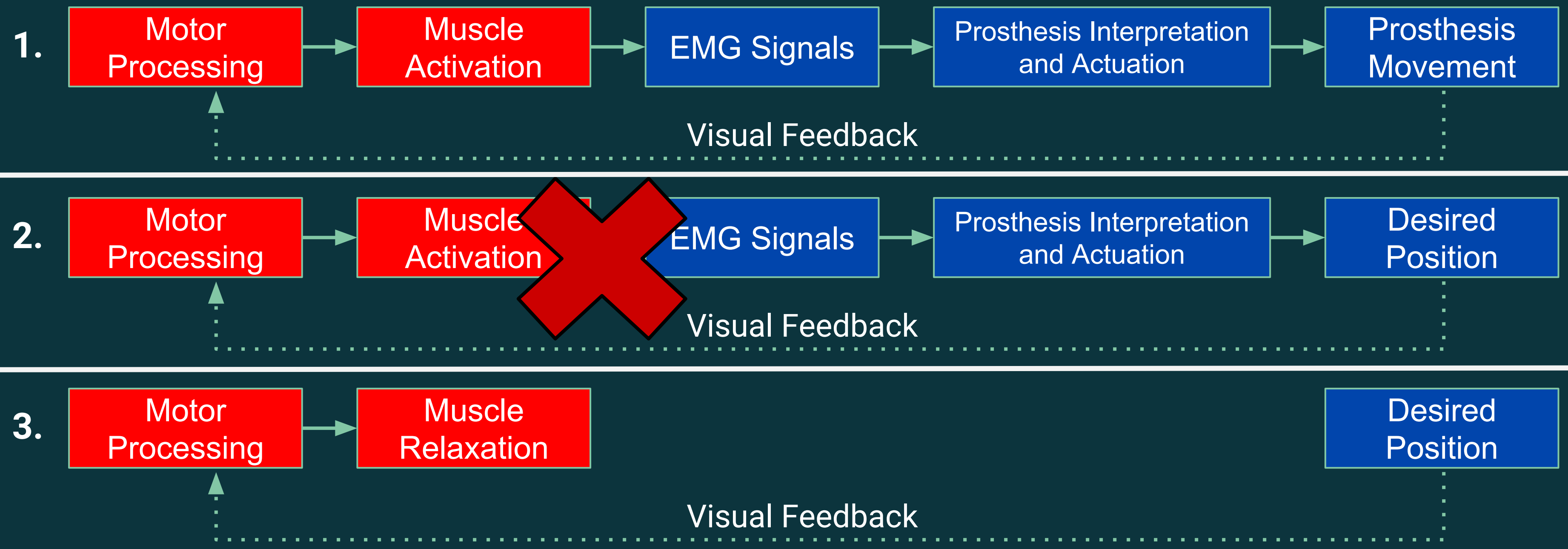
Natural Muscle Control

Key Features:

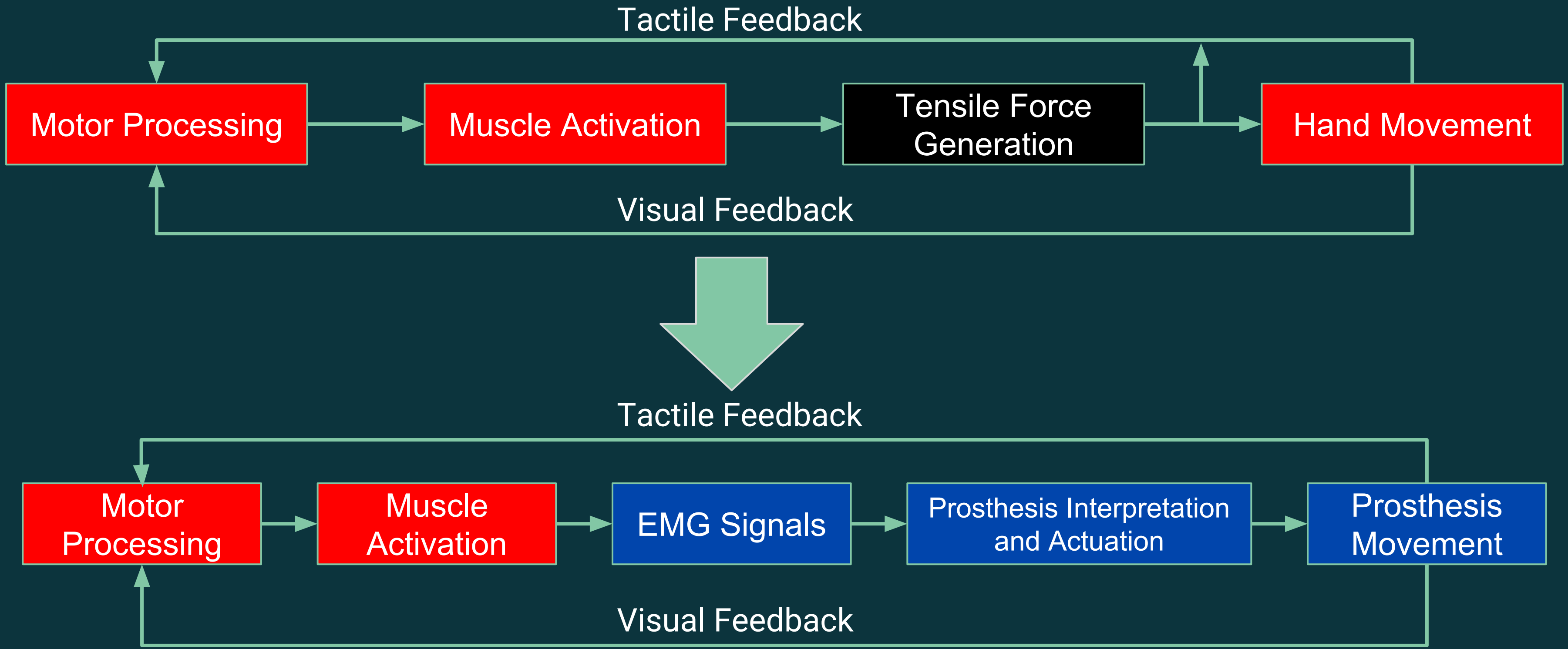
1. Continuous sensory-motor control
2. Tactile + visual afferent feedback
3. Constant motor processing and hand movement coupling



Current Velocity-Based Myoelectric Control

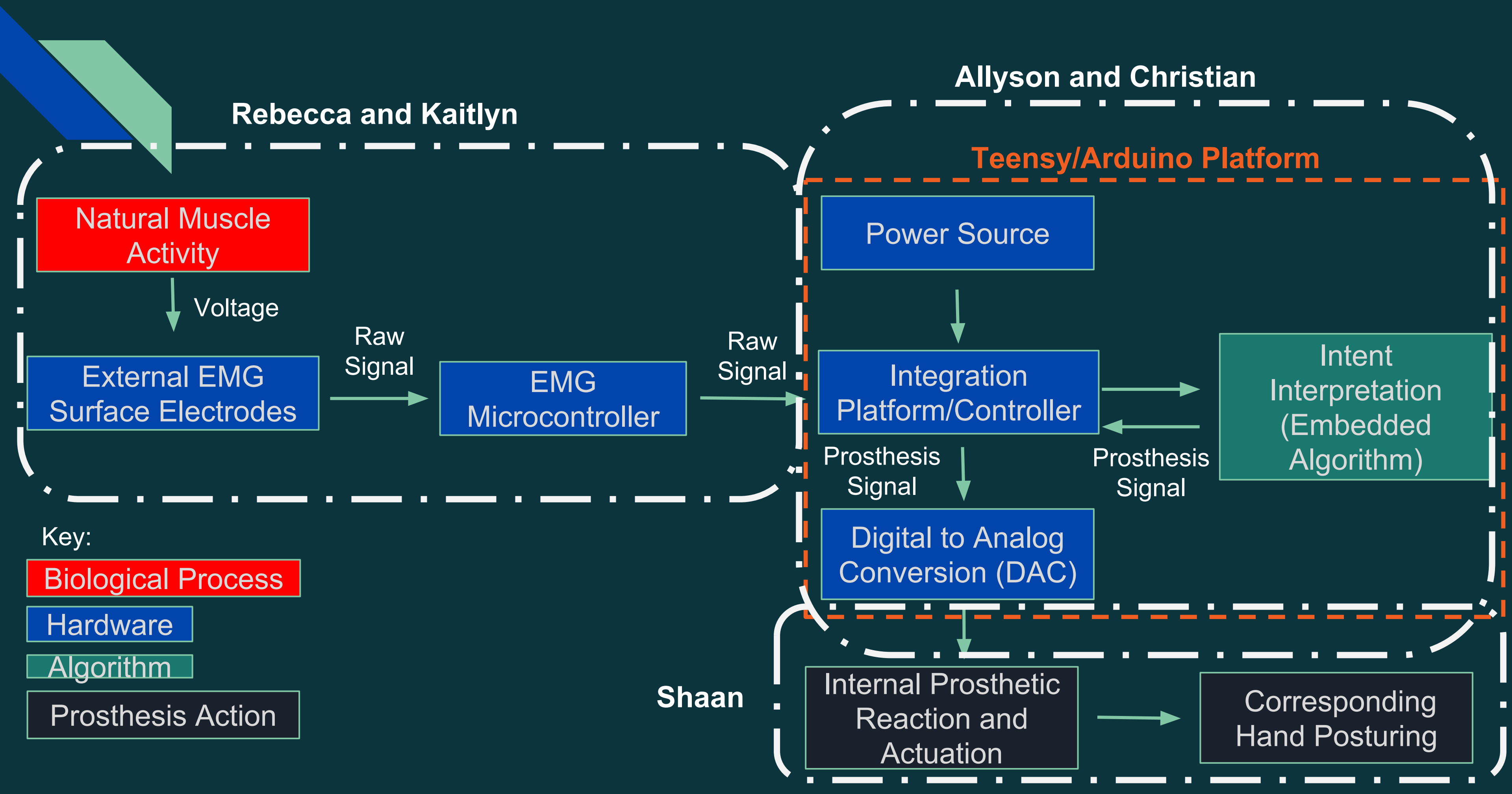


Our Role: Bridging a Gap



Highlights of Needs Assessment

- **More natural control system**
- **Adjustable to different patient capabilities**
- **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


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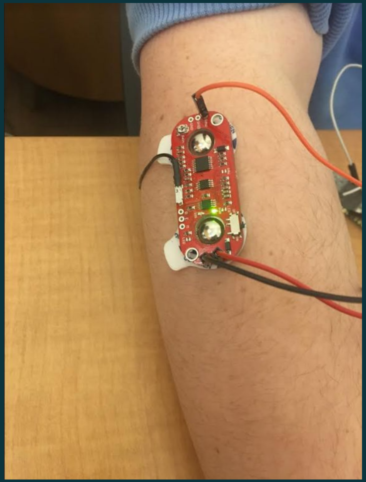
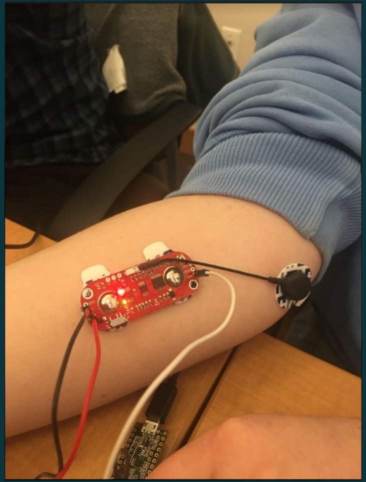
Internal Prosthetic Reaction and Actuation
Corresponding Hand Posturing
Key:
Biological Process
Hardware
Algorithm
Prosthesis Action

EMG Data Acquisition



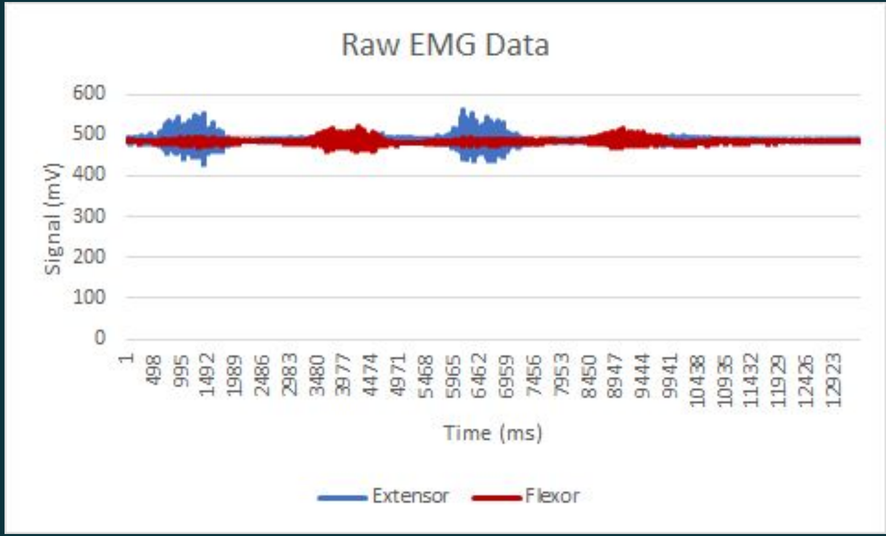
Extensor

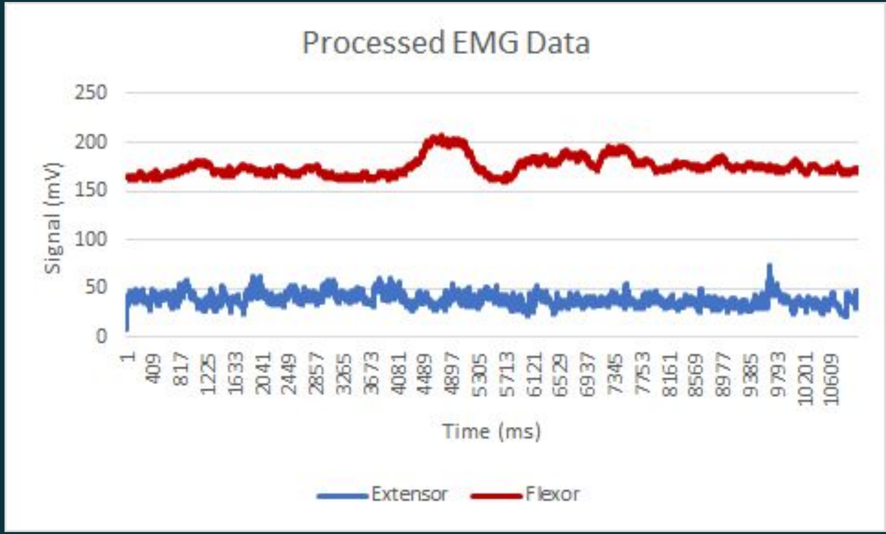


Flexor

- Phantom testing designed with human subject
  - Motion was limited where appropriate for correct signal acquisition
  - Flexed and extended wrist to maximize muscle activation
  - Tested all team members to find signal with best SNR and highest consistency
  - SNR was calculated with the average peak amplitude of contraction and average amplitude at rest
- Surface electrodes used for testing
  - Two on extensor digitorum, two on flexor digitorum, ground on elbow

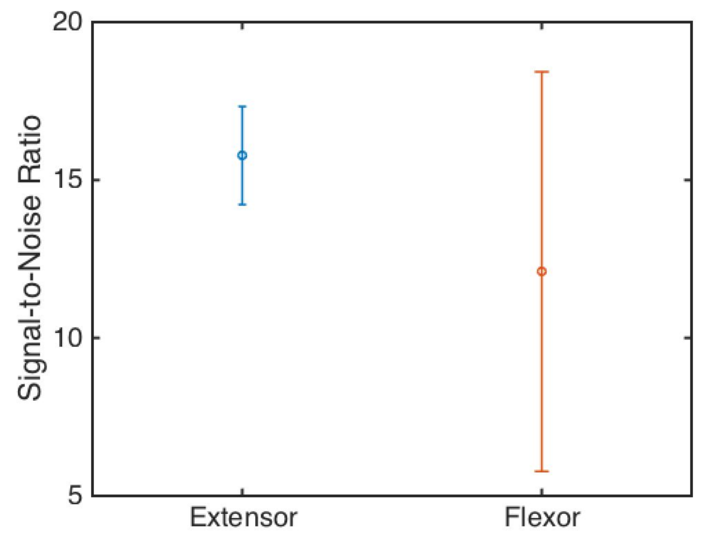
Example Output from Myoware Sensors

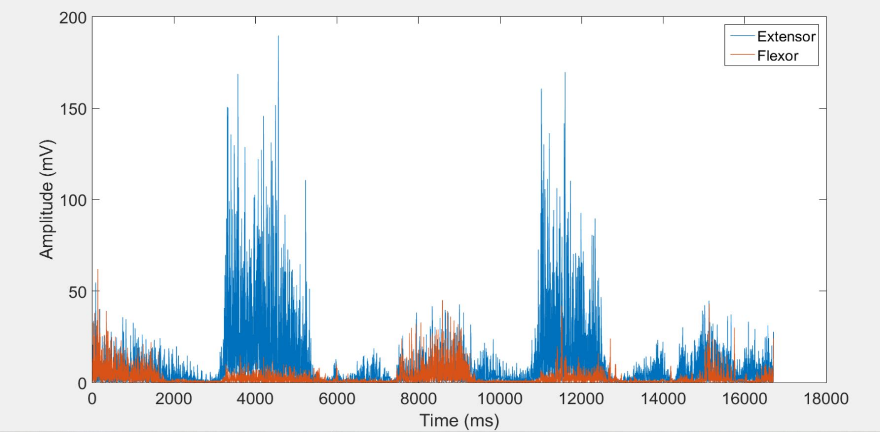




SNR Calculation

- Obtained raw signal for each test subject
- Isolated areas of extension, flexion, and rest
- Data were manually filtered
- Calculated SNR using: 20 $\log_{10}$ (|signal|/|noise|)
- Determined subject with highest SNR
- SNR for phantom tester
  - Extensor: 18.9
  - Flexor: 13.9





Hardware: Prosthesis

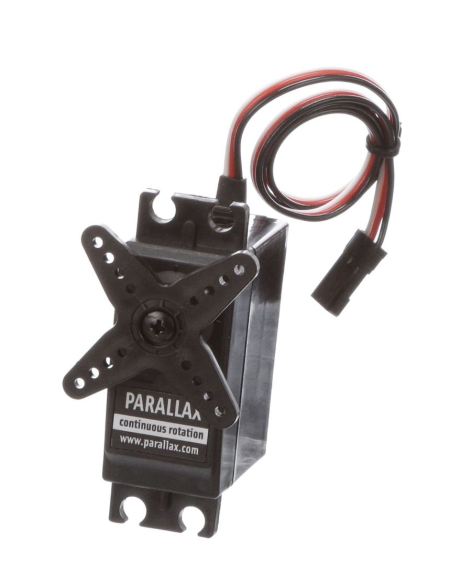
Ottobock Transcarpal Hand (8E44)

- Attempted troubleshooting
- Continued communication with Ottobock
- Future plan
  - **Moving forward with servo motor**
  - Sending hand for servicing

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: Servo

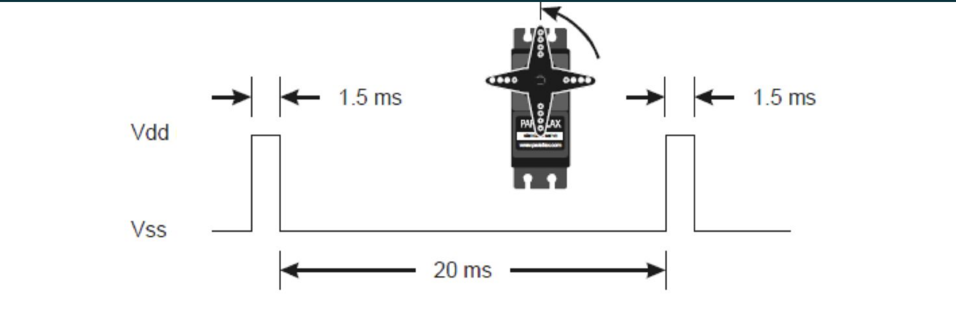
- Parallax 900-00005
- 5V operating voltage, 3.3V pulse amplitude
- Various pulse widths in a range of 0.75 to 2.25 ms



https://www.alliedelec.com/product/parallax-inc/900-00008/70372373/?&mkwid=syhLt5atl&pcrid=30980760979&pkw=&pmt=&gclid=EAIaIQobChMIo8S-iuvI4AIVKrazCh3UPAIiEAQYBCABEgJ_1vD_BwE&gclsrc=aw.ds

Servo Actuation

- This Week:
  - Map pulse widths with various angles using Arduino code
  - Determine if pulse widths map to angles or changes in angles
  - Use this information to determine what the PID output should be

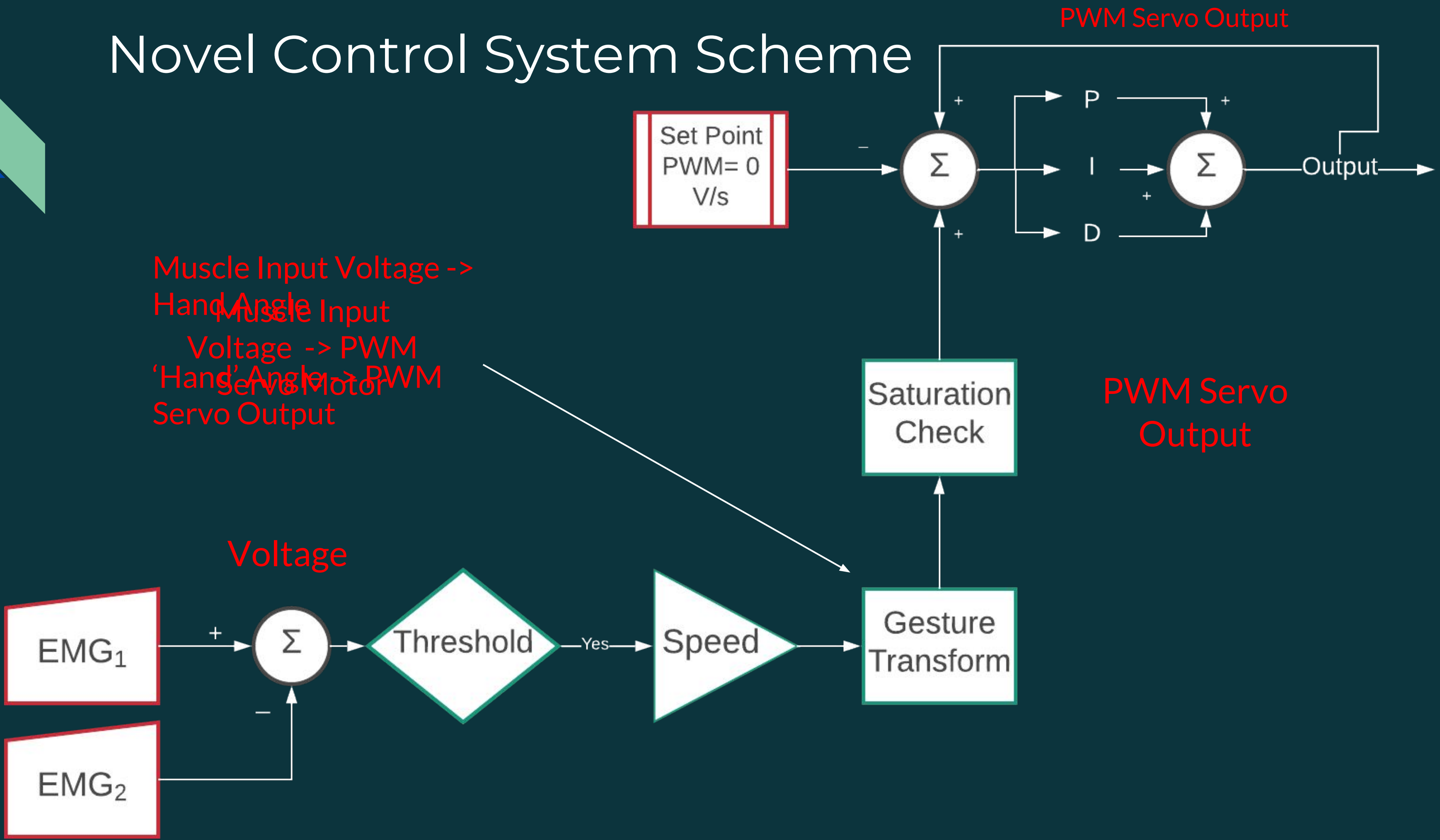


https://www.alliedelec.com/m/d/80da459fe8d684abcc085d1d7ed50e70.pdf

Hardware: External Processing

- LED Shield
  - Increased Intuitiveness for user
    - Calibration
    - Observation/Quantification of muscle fatigue
- Simplified circuit for wearability
  - Independent power source for EMG

Novel Control System Scheme



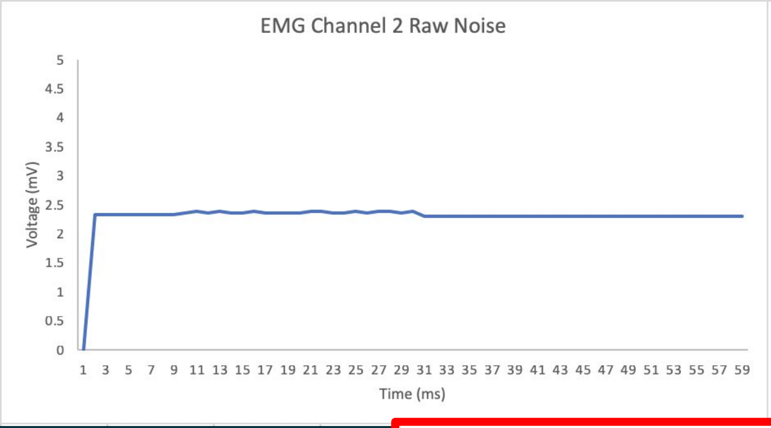
Software and Algorithm Dev

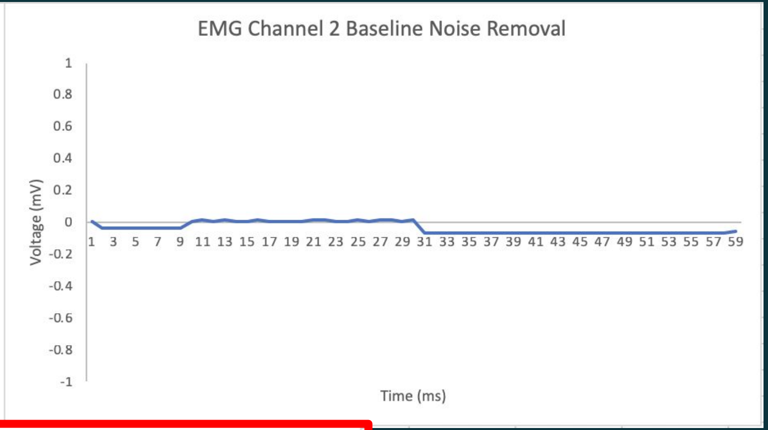
To do	In progress			Done
	Plan	Code	Test	
Supervisory Control	Actuation Output	Signal Differential	PID Controller	Data Sampling
Safety Integration	Saturation Check	Variable Speed Extraction		Myoware Calibration
Abstraction		Gesture Transformation		Digital Signal Pre-processing
		Thresholding		

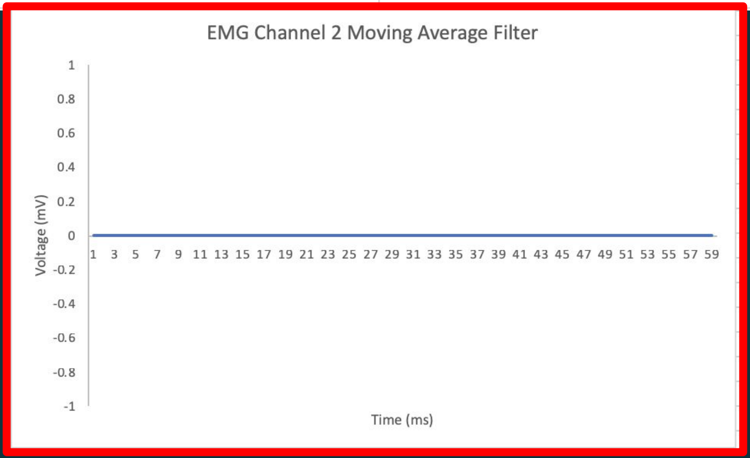
Software and Algorithm Dev

```
Calibrating channel 2:
Calibration: keep muscles relaxed for 10 s
EMG Mean is: 2.38
Relaxed calibration complete
Calibration: perform MVC for 5 seconds
MVC calibration complete
0.00
0.00
0.00
0.00
0.00
0.00
0.00
0.00
0.00
0.00
0.00
0.00
0.00
0.00
0.00
0.00
0.00
0.00
```

Software and Algorithm Dev







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

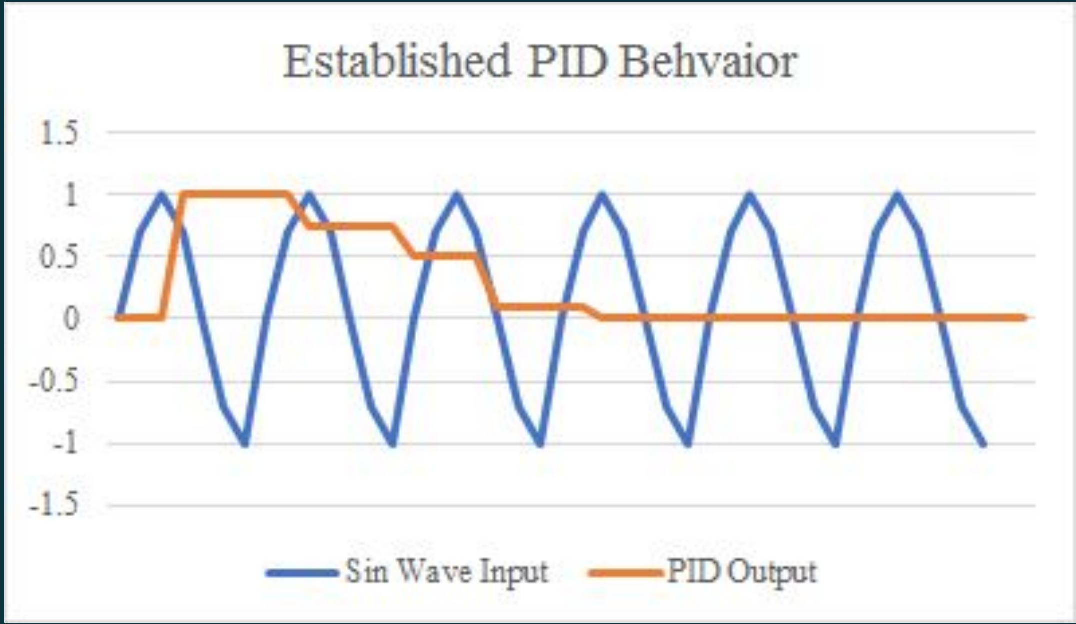
Slide 10 Figure:
https://www.researchgate.net/figure/The-muscles-related-to-finger-motion-The-muscle-functions-are-as-follows-the-flexor_fig6_258378736

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


Established PID Behvaior
1.5
1
0.5
0
-0.5
-1
-1.5
Sin Wave Input
PID Output

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

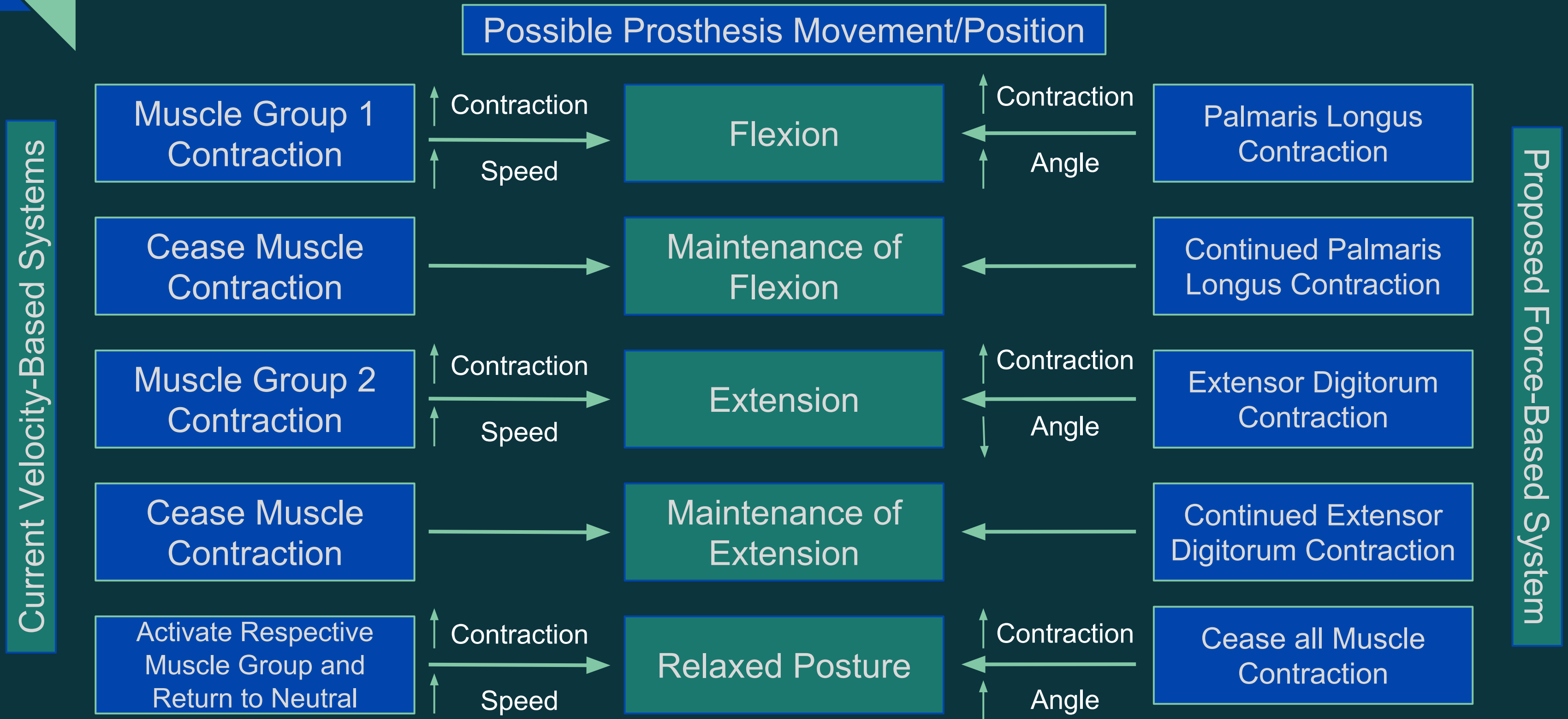
- Wearable
  - Processor either in sleeve above the prosthesis or incorporated into the prosthesis itself
  - Must be tolerable weight for daily use
- Safety
  - Must be designed and built according to quality standards to ensure there are no safety hazards from the mechanical or electrical components
  - 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

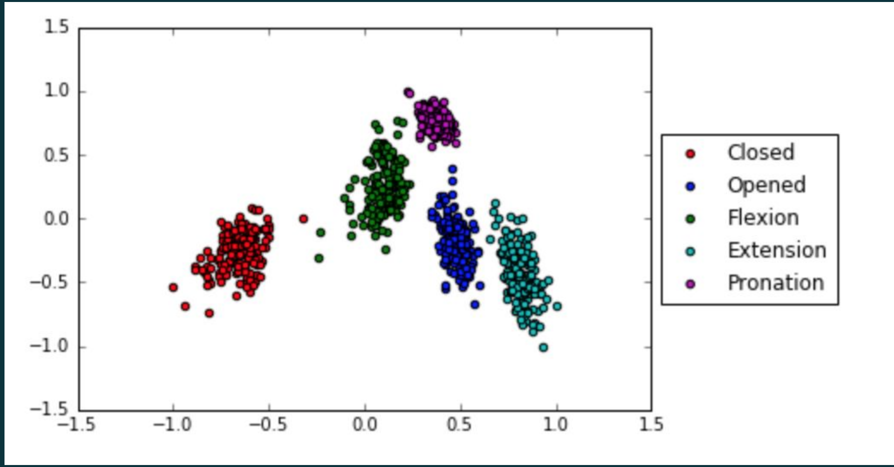
Needs Assessment: System

- 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

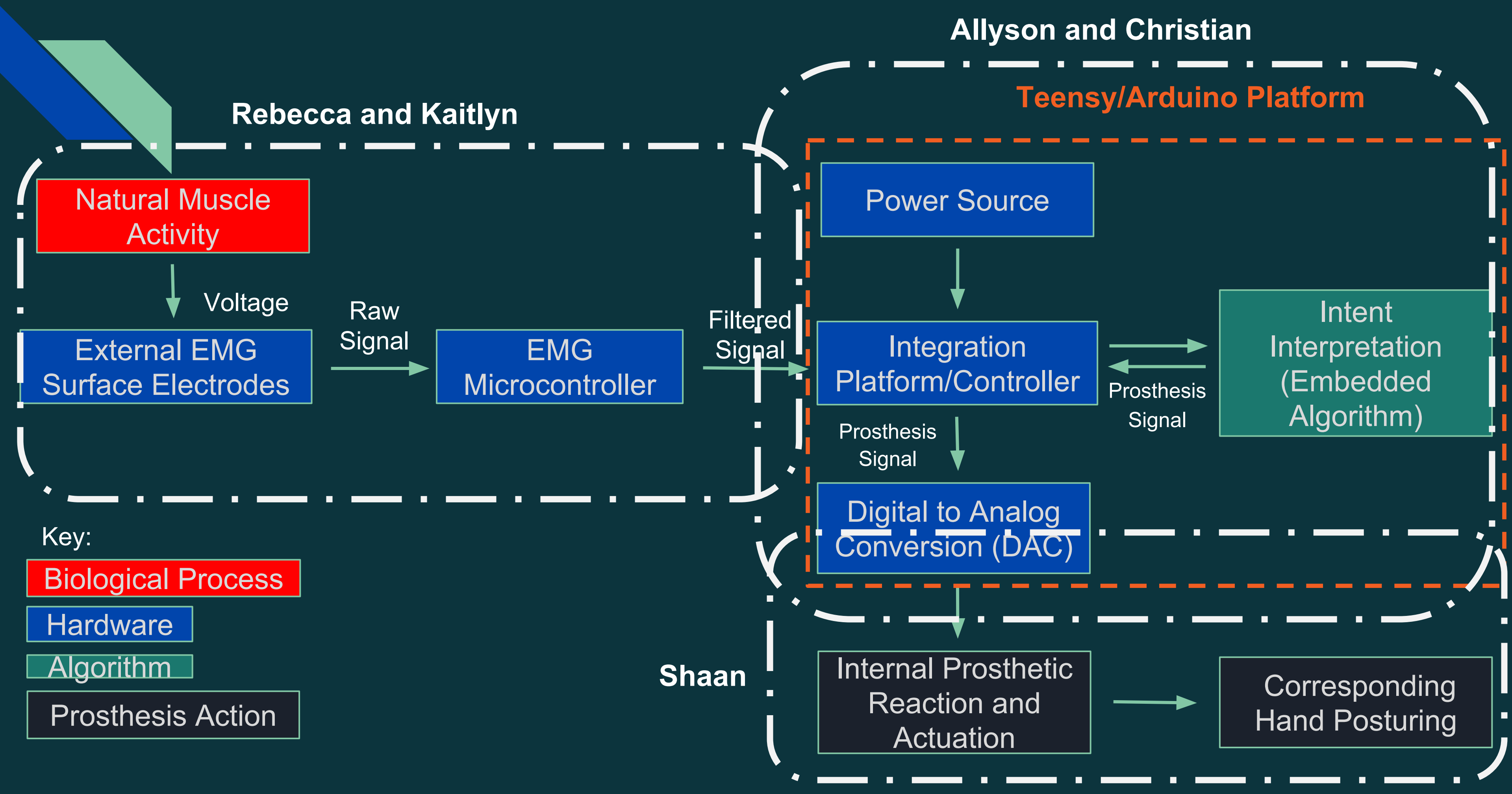
- To do this, Root Mean Square calculates the mean power of the signal, mean absolute value calculates contraction level, and waveform length shows the cumulative length of the waveform



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

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

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



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