CPS: Synergy: Sensor Network-based Lower-Limb Prosthesis Optimization and Control

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BACKGROUND

More than one million people are living with lower-limb amputation in the United States, including a large number of warfighters who lost their limbs in the military missions.

Clinical Barriers:
Increased energy expenditure may result in amputees induced fatigue, secondary body damage, asymmetric joint loading, and increased risk of falls, etc.

Technical Challenges:
Though state-of-the-art lower-limb prostheses may provide net-positive power to reduce amputees' energy expenditure, however,

- Prostheses might not work at the best condition that may maximally reduce user's energy expenditure using current prosthetic tuning services;
- Prostheses are designed and tuned for optimizing the level walking; amputees would have difficulty in slope/stair walking, and/or walking on uneven plain.

OBJECTIVES AND SPECIFIC AIMS

The objective of this project is to develop Cyber-Physical Systems (CPS) technology for the prosthesis optimization to minimize the user's energy expenditure and for extending the capacity of the prosthesis to adapt to dynamic situations and environments.

Specific Aim #A: Design of a wearable body area sensor network system and computational algorithms for real-time measurement of the user's physical load and mental effort to support personalized prosthesis optimization for the goal of maximally reducing the user's energy expenditure;

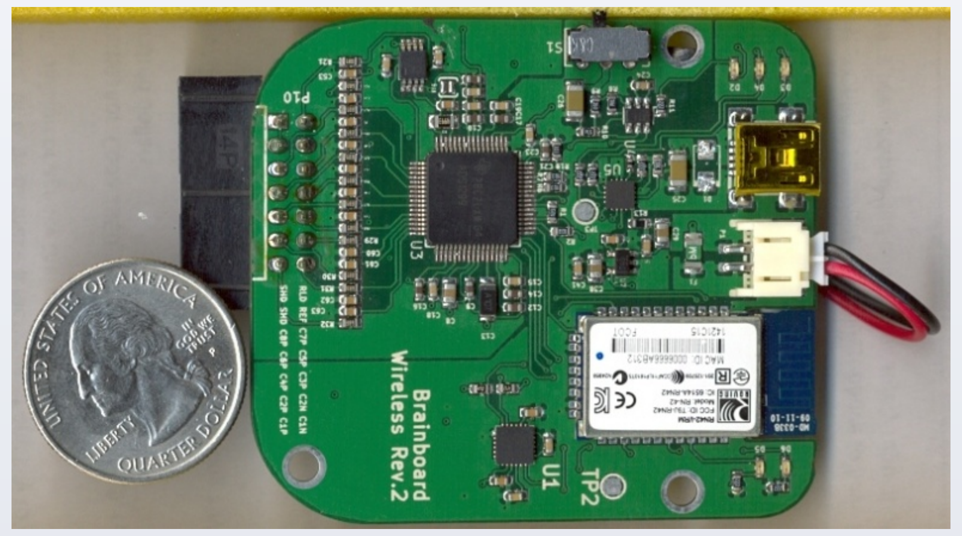
Specific Aim #B: Development of volitional prosthesis control technology for comfortable and effortless user control of prosthesis to adapt to altered situations and environments.

IMPACT

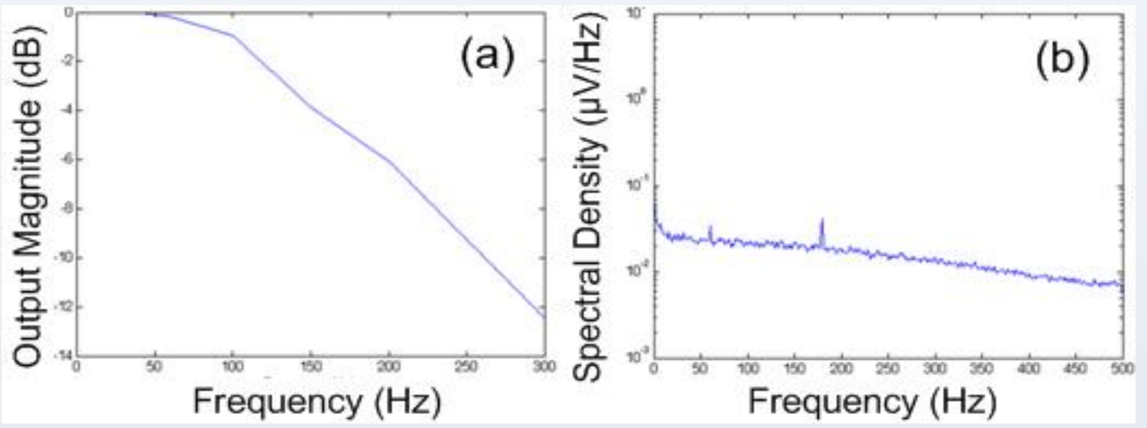
The prosthesis optimization as well as the user control of prostheses will promote a natural gait and minimize amputee's energy expenditure in prosthetic use. An optimized prosthesis with user control capability will increase equal force distribution and decrease the risk of damage to the intact limb from the musculoskeletal imbalance or pathologies. Maintenance of health in these areas is essential for the amputee's quality of life and well-being.

PROJECT PROGRESS

A. Design of a low-cost, wireless-enabled, wearable body area sensor device

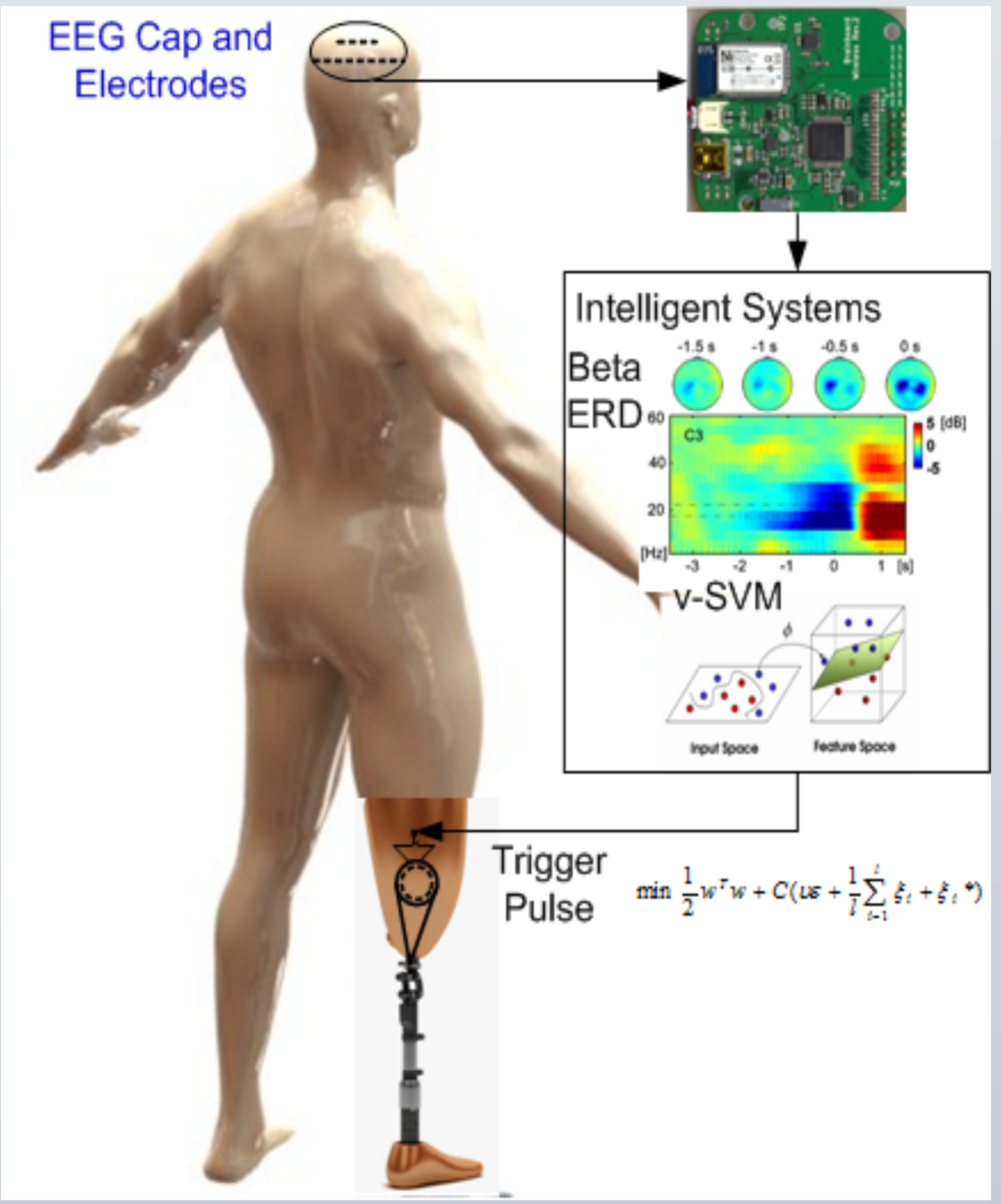


Light-Weighted, Low-Power Consumption, Battery-Powered and Wireless-enabled Body Area Sensor



BrainBoard Frequency Behavior (a) and Noise Spectrum for Shorted Inputs (b)

B. User Control of Prosthesis Directly from Brain



Volitional control of knee-locker switch for smooth walking

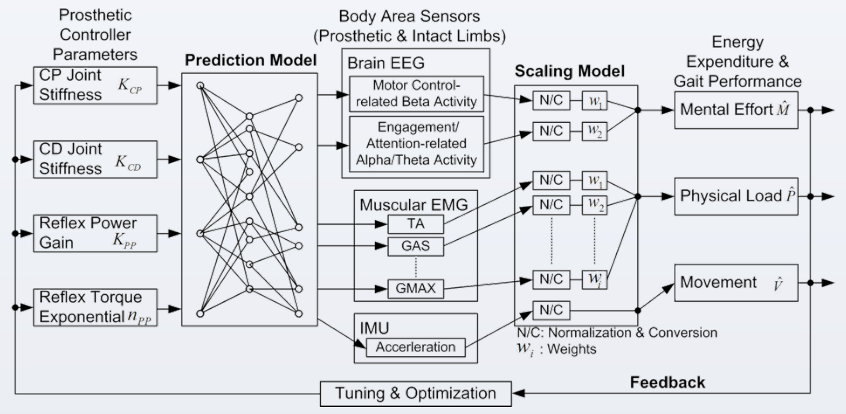
- Electrode Setup: Seven Electrodes (small metal disks) over central motor areas on the two hemispheres (C5, C3, C1, CZ, C2 and C4);
- Sampling Rate: 1000 Hz;
- Feature Extraction:
  - Spatial Laplacian transform to enhance EEG resolution
  - Event-related desynchronization (ERD) estimation from power spectral density $ERD_R = P_{ref} - P/P_{ref}$;
- Volition Recognition Algorithm:
  - Location: motor areas over two hemispheres;
  - ...eta Band (16-32Hz); ...chine with a density model of radial ...).

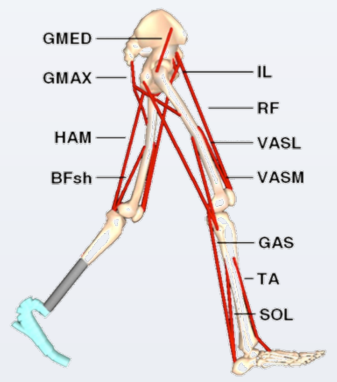
Preliminary test of Success rates from an amputee: The average sensitivity of the volitional control across eight attempts was 83.5% ±17.5%. (100%; 77.8%; 100%; 100%; 50%; 83.3%; 71.4%; and 85.7%)

No false positives were observed across ten sessions with each session of twenty volition detections.

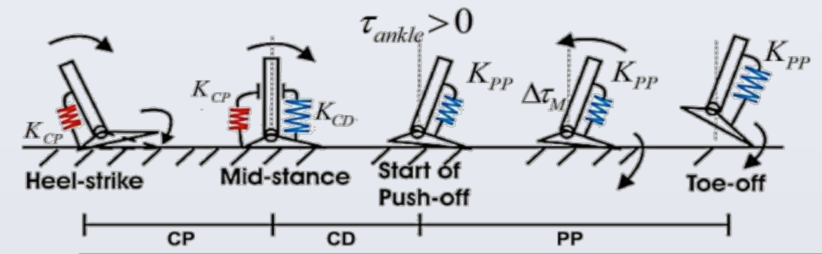
FUTURE STUDY

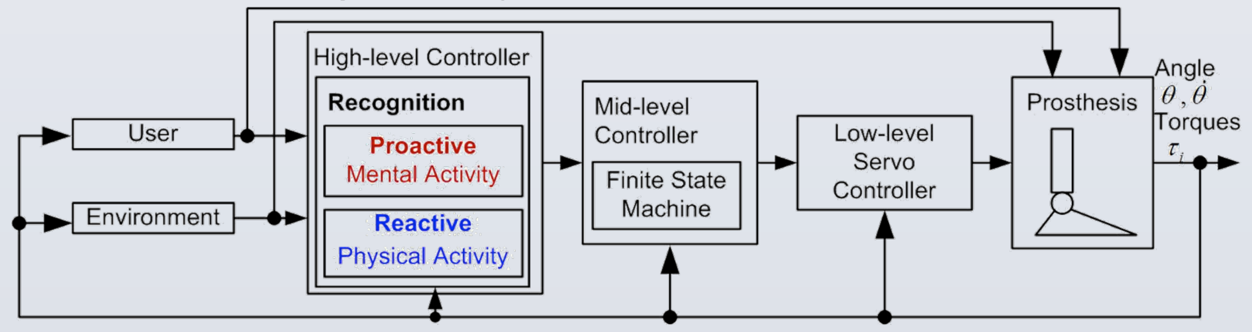
Minimizing Energy Expenditure in Amputees





User Control of Prosthesis using a Brain-Computer Interface-based Volition-Recognition Technology





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Healthier & Better Walking