Review: Upper Limb Prostheses

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ULP Classifications

- Cosmetic
- Body-powered
- Externally-powered
  - Open/Close
  - Multi-finger
  - Multi-functional

Image source: [1-3], Data source [3]
Myoelectric Prostheses

- Using biological signals to control movement of prosthetic
Myoelectric Prostheses

- Uses electrodes to measure action potential
  - Normally obtains signal from two positions for opening/closing
- Emissions measured on skin surface
  - Microvolt level
- Electrodes
  - Signal amplified to use as controls for prosthetic motors
  - External source (6V battery) needed to operate motor

Data source [3]
Myoelectric Prostheses

• Flow diagram

Arm → Electrodes → Amplifier → EMG Signal

Prosthesis ← DAQ ← DSP

1. Feature extraction
2. Classification of signal

Data source [6,7]
Electrode Considerations

- Factors affecting EMG signal
  - Muscle atrophy
  - Muscle displacement after amputation or injury
- Changes in signal pattern over time
  - Electrode position
  - Sweat
  - Fatigue
Electrode Considerations

- **Konishi et al.**
  - **Purpose:** find optimal electrode position
  - **Band-type multi-electrode**
    - Ag-AgCl (10mm diameter)
    - Impedance converter
  - **Myoelectric signal amplifier**
    - Amplifier gain: 60dB
  - **Data processing**
    - Sampling Freq at 1 kHz
    - Two processing types: full wave rectification & 10Hz low-pass filtering to get IEMG
  - **Display data:** Radar plot IEMG

Data source [6]
Electrode Considerations

• Factors affecting EMG signal
  - Muscle atrophy
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Classifier

- Classifies extracted features into desired motion patterns
  - Herle et al:
  - Ex: Feed-forward neural network (FFNN)
    - Extension, flexion, pronation, supination
  - Feature extraction: amplitude, power spectrum, time-domain
Classifier

Figure 1. System architecture

Figure 5. Neural network architecture

Data source [6]
Classifier

- More degrees of freedom requires
  - More motors and more complex classification system
- Boschmann approach
  - Support Vector Machines (SVMs) used for robust, comprehensive classification
Myoelectric Prostheses

- **Pros**
  - Robust
  - Simple to implement
  - Non-invasive

- **Cons**
  - “Switch” operated
    - Limited number of channels of control
    - One joint movement at a time (2 D.O.F.)
  - Number of signal sources decreases with level of amputation
  - No sensory function

Myoelectric Prosthetic

• Touch Bionics – i-LIMB
  ▫ First commercially available “true 5-finger hand prosthesis”
  ▫ Controlled by action potential
  ▫ Two input myoelectric (SEMG)
    • Open/close fingers
  ▫ Independently driven motor in each finger
    • Computer in the back of the hand: interprets signals from electrodes

Image, data source [12]
i-LIMB cont’d

- **Drawback**
  - Finger control coupled with open/close function, so not completely independent
  - No sensory control to control grip strength
    - Pre-programmed grip patterns to learn
  - Signal not physiologically relevant
Multi-function

- Myoelectric Summary
  - Effective but limited
  - Non-physiologically relevant signals
    - Causes control complexity, complicates user training

- To circumvent:
  - Targeted Muscle Reinnervation (TMR)
  - Implanted electrodes
Targeted Muscle Reinnervation

- Neural-machine interface
  - Takes nerves that innervated severed limb, redirects them to proximal muscle and skin sites
  - Redirect high to low functional significance

Image source [14], Data source [15]
Targeted Muscle Reinnervation

- Muscles serve as biological amplifiers of motor commands
- Bipolar EMG electrodes placed on skin over reinnervated muscles

Image source [14,17], Data source [16]
Targeted Muscle Reinnervation

Data source [24]
Targeted Muscle Reinnervation

• **Pros**
  ▫ Simultaneous control of multiple D.O.F.
    • 14/21 D.O.F. (DeKa)
  ▫ Natural feel, connection to nervous system
  ▫ Potential for sensory feedback
    • TSR

• **Cons**
  ▫ Invasive
  ▫ Controlling EMG signal isolation
  ▫ SEMG concerns

Data source [17, 18]
Implanted Electrodes

- Neuroprosthetic interface
  - Allows for sensory feedback and higher number of control channels
  - Four miniature electrodes (thin-film longitudinal intra-fascicular electrodes [tfLIFE]) implanted in the nerve

Image source [19, 20], data source [19,11]
Implanted Electrodes

• Pros
  ▫ Accurate, complex hand movement allowed
  ▫ Hand movement truly controlled by thought

• Cons
  ▫ Implant remains in patient only a month at a time
  ▫ Technology not yet perfected
  ▫ Invasive

Image source [21], data source [11]
Future Steps

- Ultimate goal:
  - Arm that ties directly into nervous system
- Increase degrees of freedom of prosthetic arm
- Feature Extraction
  - Optimizing classifier
- Sensory Functions
  - Targeted Sensory Reinnervation
  - FILMskin

Data source [22]
Future Steps

- Electrode technology (tfLIFE)
  - Biocompatibility
  - Integrity of signal
- Darpa Funded
  - JHU Applied Physics Laboratory
  - Rehabilitation Institute of Chicago
  - DeKa Research (Dean Kamen)
- European Union Funded
  - University of Rome (Bio-Medical Campus)

Data source [24]
References

13. PD Marasco, et al. “Sensory capacity of reinnervated skin after redirection of amputated upper limb nerves to the chest” Brain; 2009: 132; 1441-1448
16. PD Marasco, et al. “Sensory capacity of reinnervated skin after redirection of amputated upper limb nerves to the chest” Brain; 2009: 132; 1441-1448