Review: Upper Limb Prostheses

By Edward Yip

ULP Classifications

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

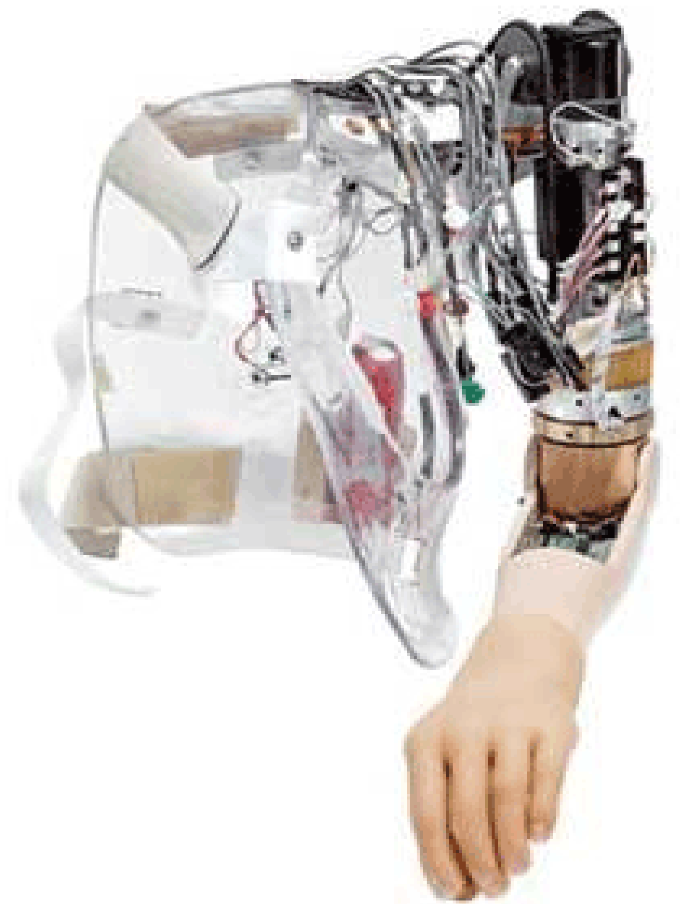
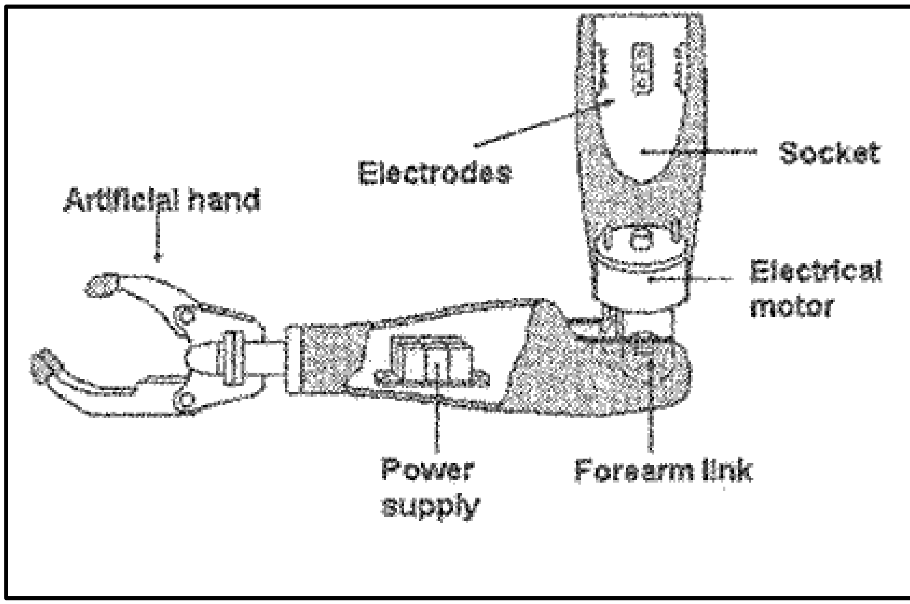


Image source: [1-3], Data source [3]

Myoelectric Prostheses

- Using biological signals to control movement of prosthetic



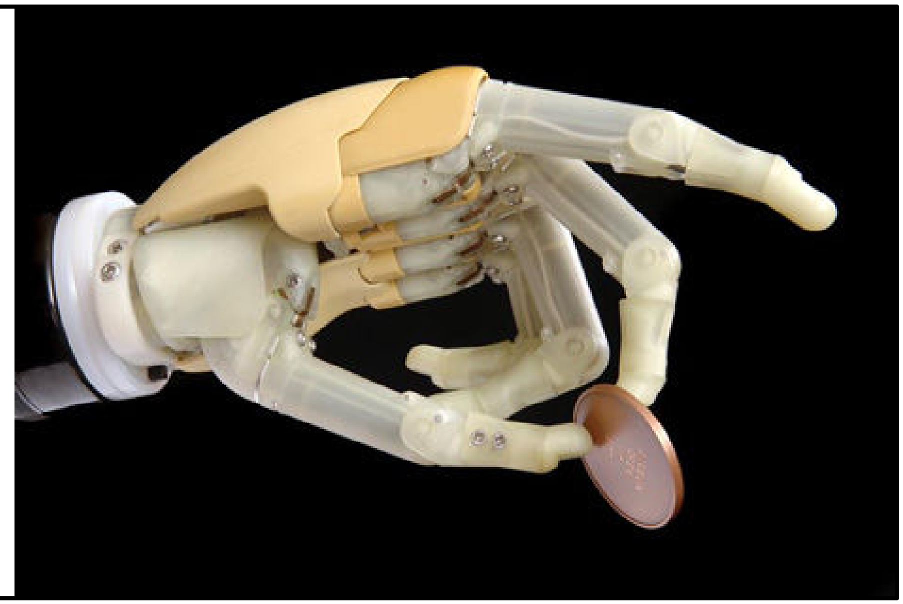


Image source [4,5]

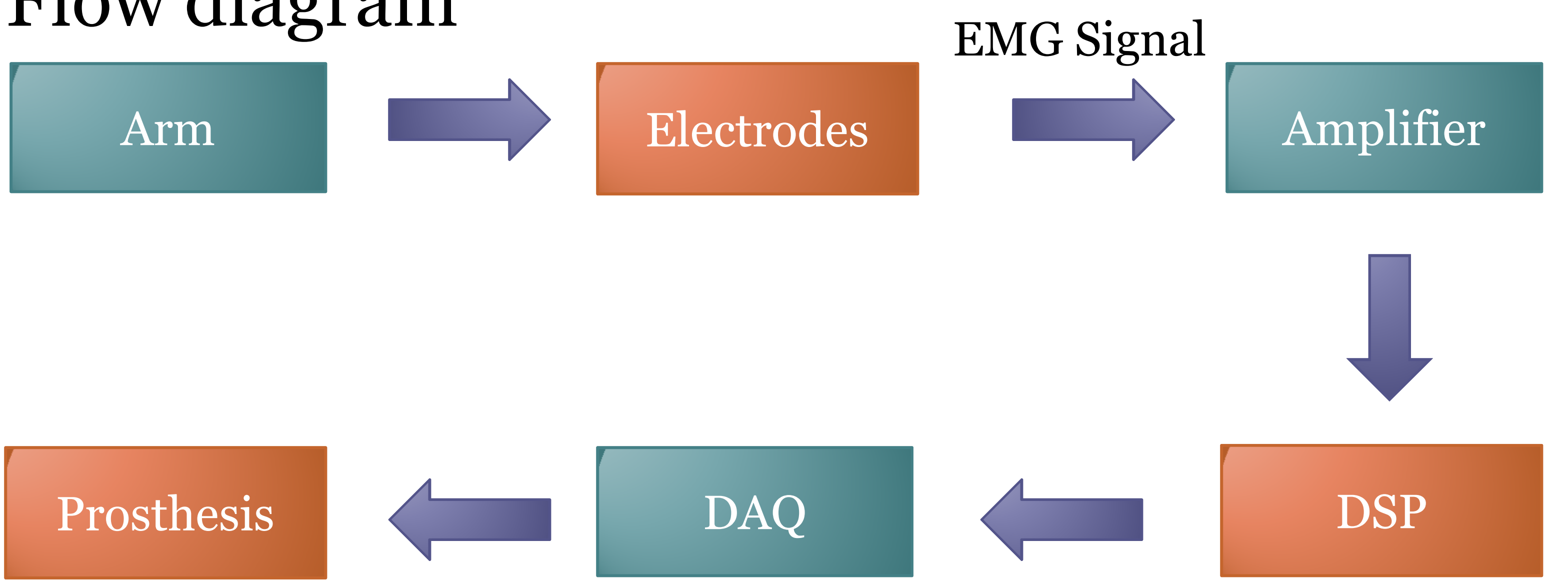
Myoelectric Prostheses

- 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



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

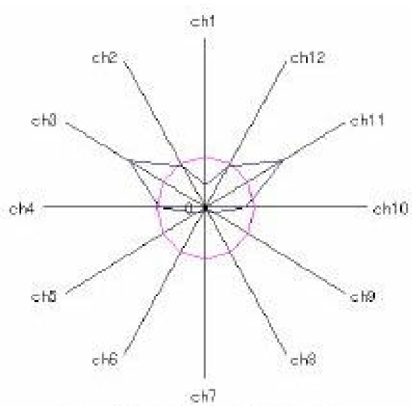


Fig.4.1.a. Flexion (Subject 1)

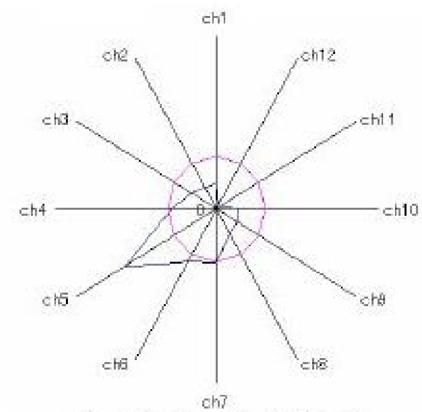


Fig.4.1.b. Extension (Subject 1)

Data source [6]

Electrode Considerations

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

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

Data source [6]

Classifier

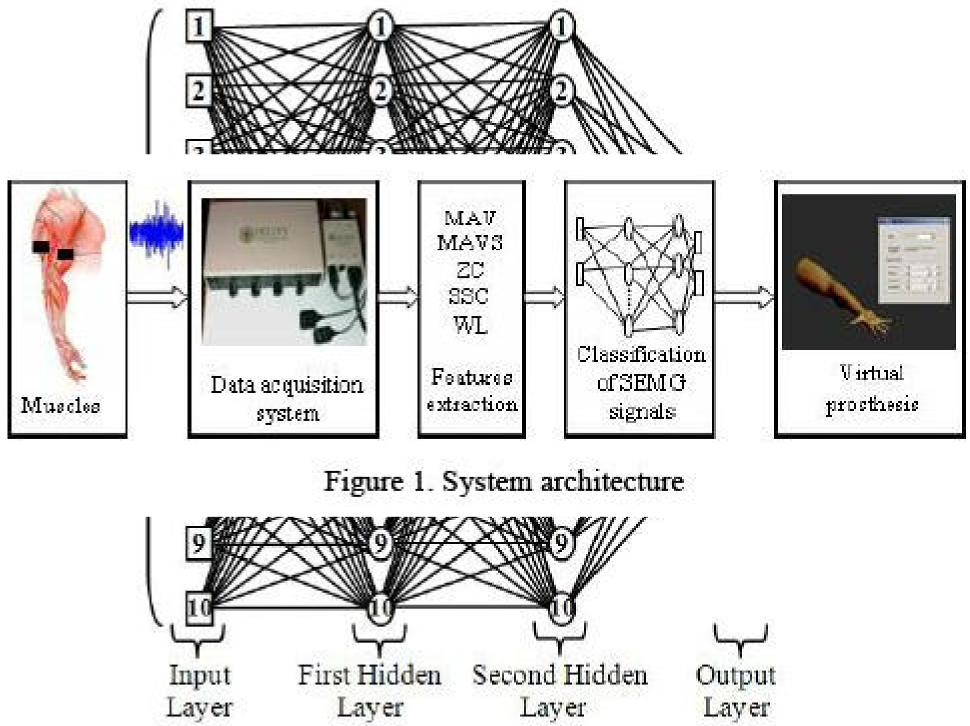


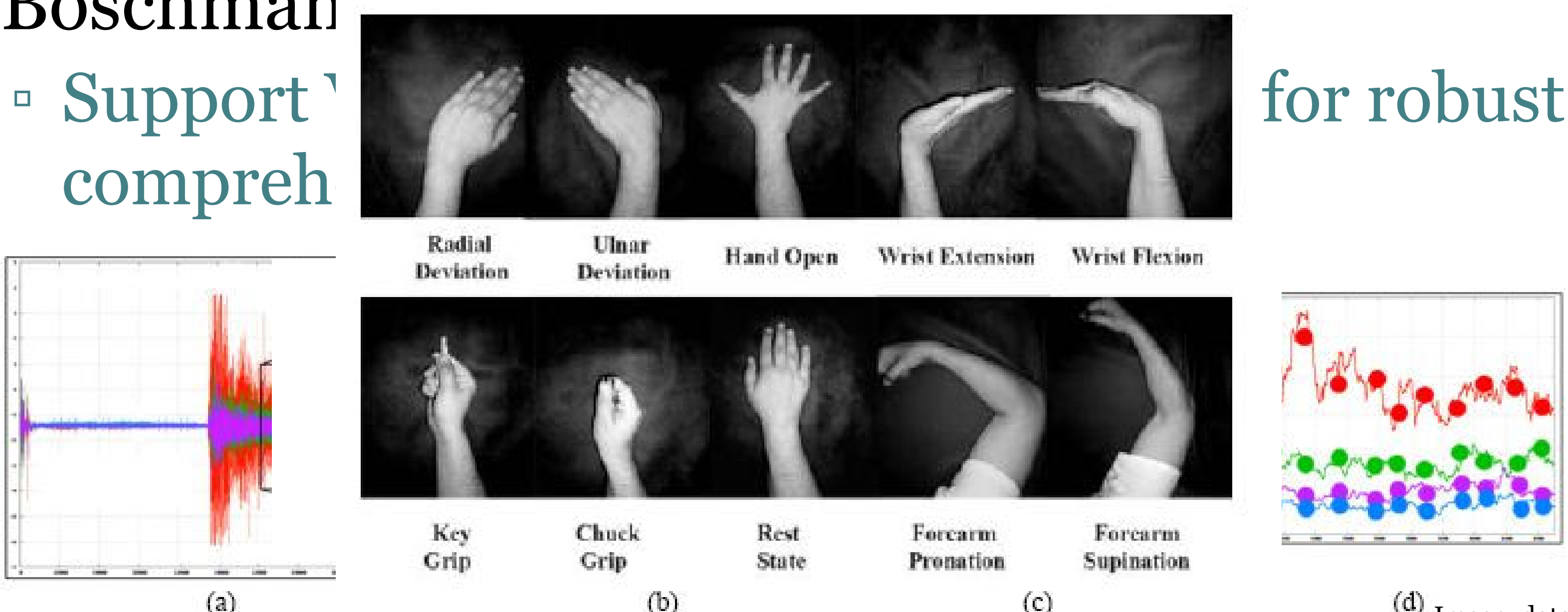
Figure 1. System architecture

Figure 5. Neural network architecture

Data source [6]

Classifier

- More degrees of freedom requires
  - More motors and more complex classification system
- Boschman
  - Support for robust, compreh



Image, data source [8,9]

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

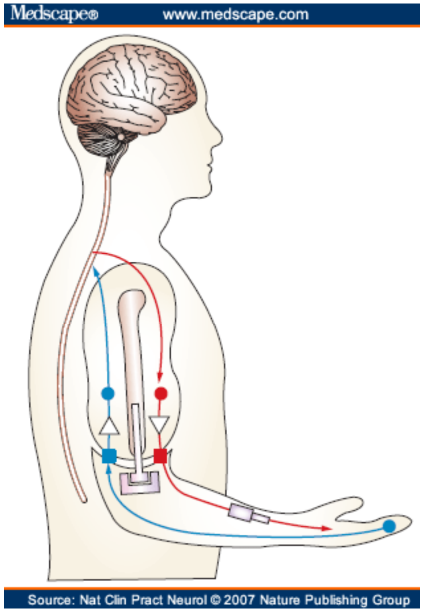
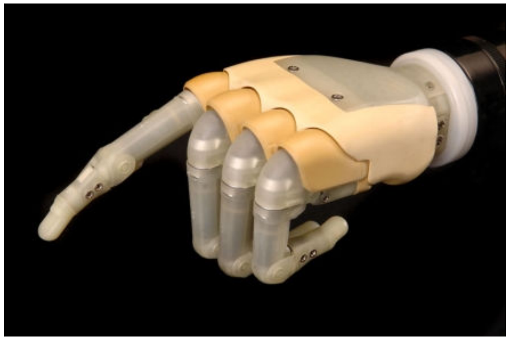


Image source [10] Data source [6, 11]

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

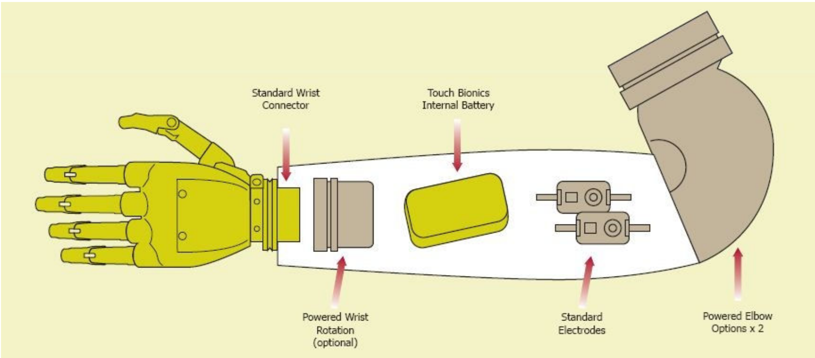


Image , data source [13]

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

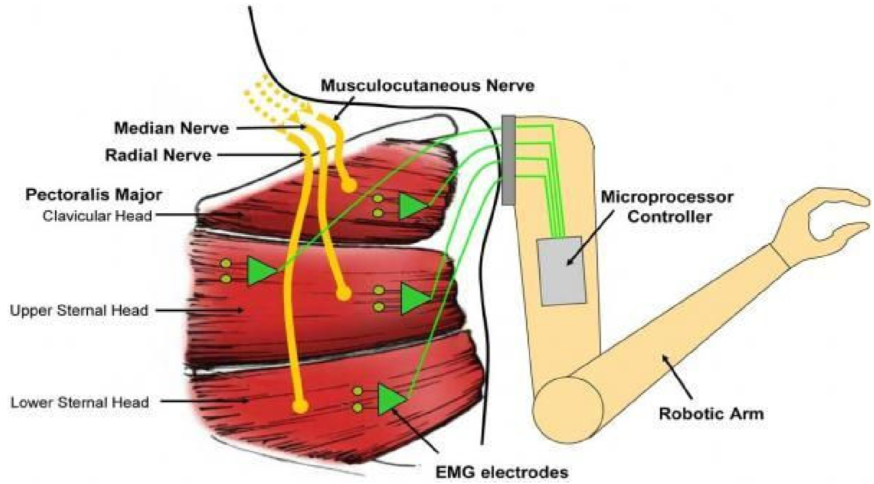
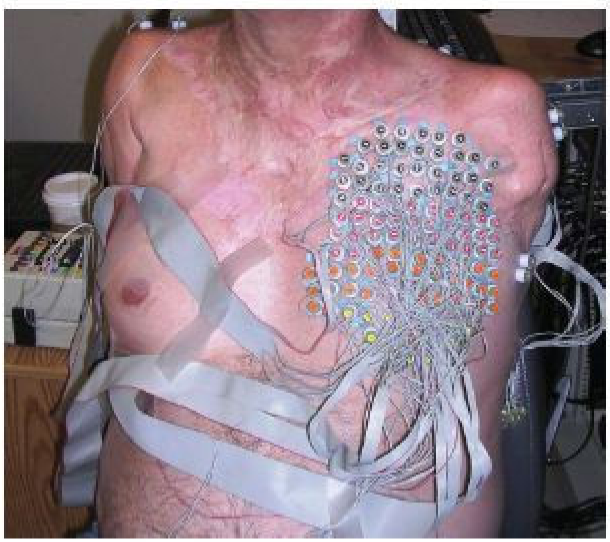


Image source [14] , Data source [15]

Targeted Muscle Reinnervation

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



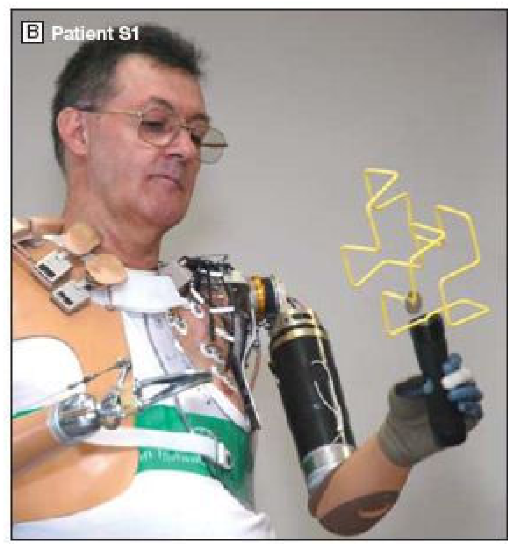


Image source [14,17], Data source [16]

Targeted Muscle Reinnervation

Data source [24]

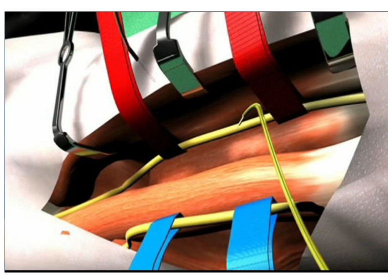
Targeted Muscle Reinnervation

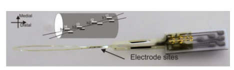
- Pros
  - Simultaneous control of multiple D.O.F.
    - 14/21 D.O.F. (DeKa)
  - Natural feel, connection to nervous system
  - Potential for sensory feedback
    - TSR
- Cons
  - Invasive
  - Controlling EMG signal isolation
  - SEMG concerns

Data source [17, 18]

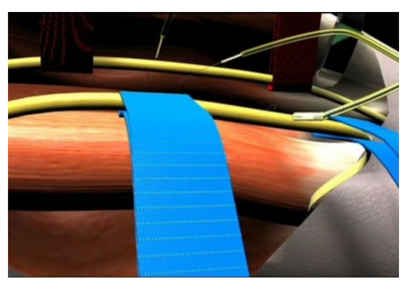
Implanted Electrodes

- 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





tfLIFE



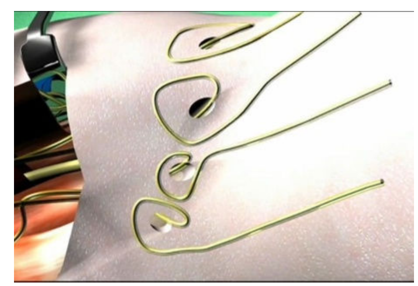
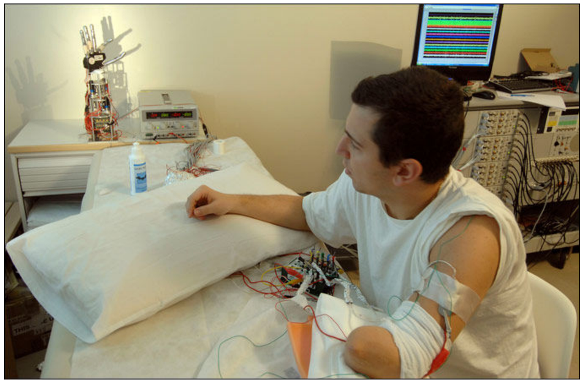


Image source [19, 20], data source [19,11]

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]

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