Intelligent Prosthesis
From Sensor Data to Motion Generation

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Motivation

- Limb prosthesis for amputees rehabilitation (approx. 10 millions of amputees over the world in 2008 [4]).
- Limb orthosis for rehabilitation of people with a violation of musculoskeletal system.
- Exoskeleton systems for assisting people in daily routines.

[www.touchbionics.com]
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Sensors

Type of Input Signals

- Electromyography (EMG)
- Mechanomyogram (MMG) or sound myogram
- Electroencephalography (EEG)
- Electrooculography (EOG)
- Electrocorticogram (EcoG)

[www.science.education.nih.gov]
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Sensors
Myoelectric Sensor

Motivation  Sensors  EMG control systems  Feedback  Nice video  References

[MyoWare Muscle Sensor DevKit, www.sparkfun.com/products/13772]

[www.mananatomy.com/basic-anatomy]
Data Segmentation

Constraints

Definition

Segment is a time slot for acquiring myoelectric data considered for feature extraction. [2]

Time constraints:

- Real time constraint: segment length + processing time ≤ 300ms
- Lower bound: 32ms

Signal state constraints:

- Transient state
- Steady state (preferred)
Data Segmentation: Windowing

- Adjacent Windowing
- Overlapped Windowing
- Continuous Segmentation (plus majority voting technique)
EMG control system
Majority Voting

- Post-processing technique.
- Smoothes class decisions.
- Class at point $t = \text{most frequent class at points } [t-m; t+m]$.

$$m \times T_{\text{process}} \leq T_{\text{delay}}, \text{ where}$$

$T_{\text{process}} = \text{time consumed during feature extraction,}$

projection and classification;

$T_{\text{delay}} = \text{acceptable response time of the control system.}$
T. Sono et al. [7] upper limb prosthesis with simple threshold control.

- Biceps deliver flexion, triceps - extension.
- Threshold $T = 20\%$ of max contraction.
  - Open if closing EMG $< T$ && opening EMG $> T$
  - Close if closing EMG $> T$ && opening EMG $< T$
  - Otherwise $\Rightarrow$ do nothing (no need to keep muscles contracted).
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- Threshold $T = 20\%$ of max contraction.
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- **Close** if closing EMG $> T$ && opening EMG $< T$
- Otherwise => **do nothing** (no need to keep muscles contracted).
Grasping object with 2 fingers (upper line) and 1 finger (bottom line). [7]
Red lines = mean values with applied low-pass filter. Red dashed lines = onset of signal.

[3]
Vectorization of data in experiment of M. Gandolla et al. [3]
Calibration procedure in experiment of M. Gandolla et al. [3]
EMG control system
Limitations

- No tactile feedback. Visual feedback is not enough to provide subconscious control.
- No individual control on some of the muscles (true for innate limbs as well).
- Necessity to concentrate and physically react during operation.
EMG control system

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Necessity to concentrate and physically react during operation.
Experiment of Hernandez A. Alejandro et al. [1].

- Uses neural plasticity to associate an unique event with new stimuli.
- Substitutes tactile feedback with an electrical stimulation in healthy arm.

- Results: brain shows activation of the sensory area related to the amputated arm.

[1]
Conclusion

- Patients are able to return to simple functional activities of daily life.
- Enhancement with biofeedback helps to prevent phantom pain and neuro reconstruction.
- Unfortunately, contemporary solutions are still inconvenient.
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Nice Video

Upper limb prosthesis from John Hopkins University, Applied Physics Laboratory: https://www.youtube.com/watch?v=-0srXvOQlu0

[www.bloomberg.com]


