



Universität Hamburg

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MIN-Fakultät
Fachbereich Informatik



Intelligent Prosthesis

From Sensor Data to Motion Generation

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Technische Aspekte Multimodaler Systeme

12. December 2016



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2. Sensors

Types

Myoelectric sensor

3. EMG control systems

System overview

Preprocessing of data

Non-pattern recognition systems

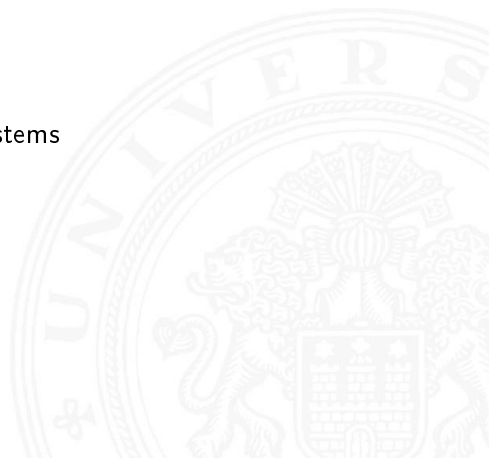
Classification with ANN

Limitations

4. Feedback

5. Nice video

6. References



- ▶ 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

Motivation

Sensors

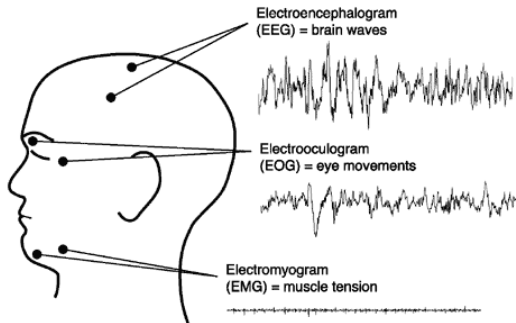
EMG control systems

Feedback

Nice video

References

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



[www.science.education.nih.gov]

Sensors

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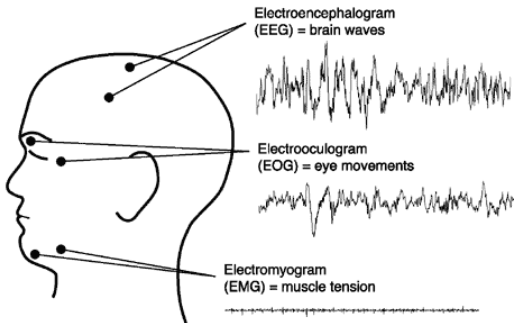
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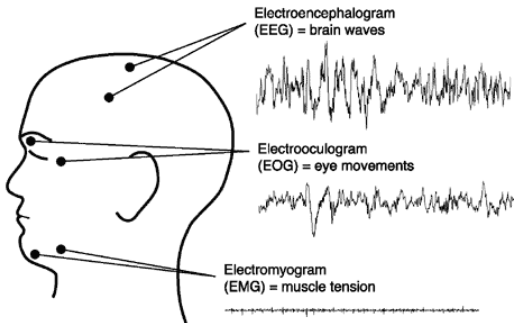
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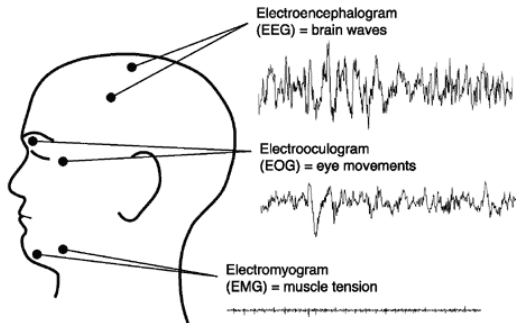
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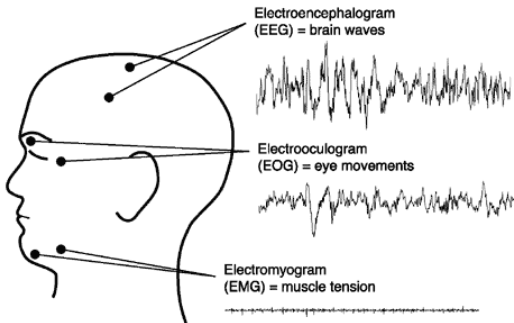
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[www.science.education.nih.gov]

Sensors

Myoelectric Sensor

Motivation

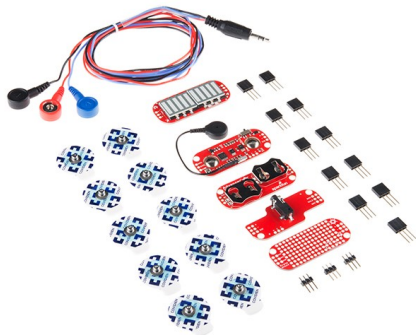
Sensors

EMG control systems

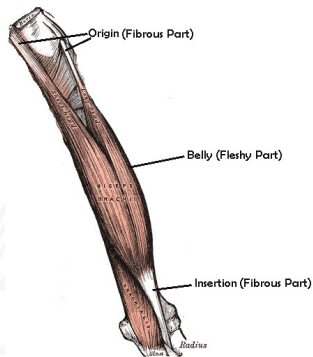
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[MyoWare Muscle Sensor DevKit,
www.sparkfun.com/products/13772]



[www.mananatomy.com/basic-anatomy]

EMG control system

Overview

Motivation

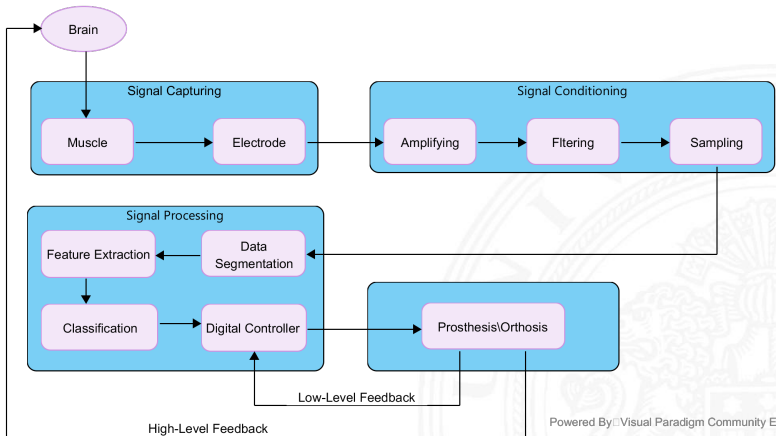
Sensors

EMG control systems

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Data Segmentation Constraints

Definition

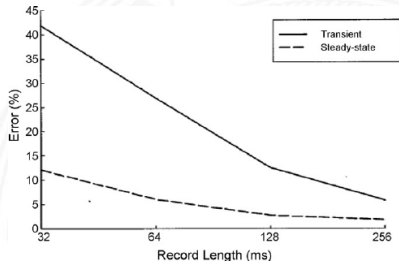
Segment is a time slot for acquiring myoelectric data considered for feature extraction. [2]

Time constraints:

- ▶ Real time constraint: segment length + processing time \leq 300ms
- ▶ Lower bound: 32ms

Signal state constraints:

- ▶ Transient state
- ▶ Steady state (preferred)



[2]

Data Segmentation: Windowing

Windowing

Motivation

Sensors

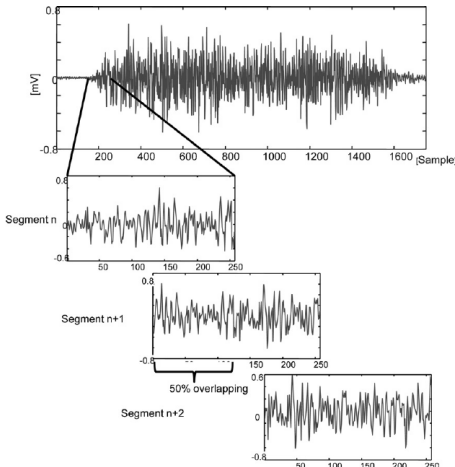
EMG control systems

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References

- ▶ Adjacent Windowing
- ▶ Overlapped Windowing
- ▶ Continuous Segmentation (plus majority voting technique)



[6]



EMG control system

Majority Voting

Motivation

Sensors

EMG control systems

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References

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

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

$T_{process}$ = time consumed during feature extraction,
projection and classification;

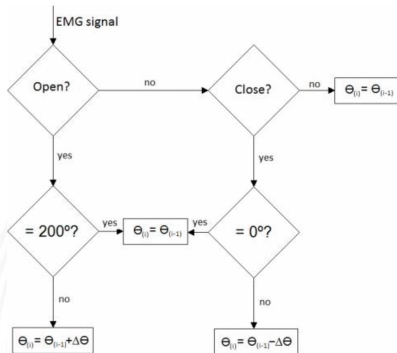
T_{delay} = acceptable response time of the control system.

EMG control system

Non-pattern recognition 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 => **do nothing** (no need to keep muscles contracted).



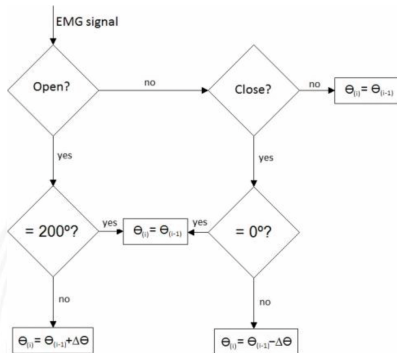
[7]

EMG control system

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[7]

EMG control system

Non-pattern recognition system (cont.)

Motivation

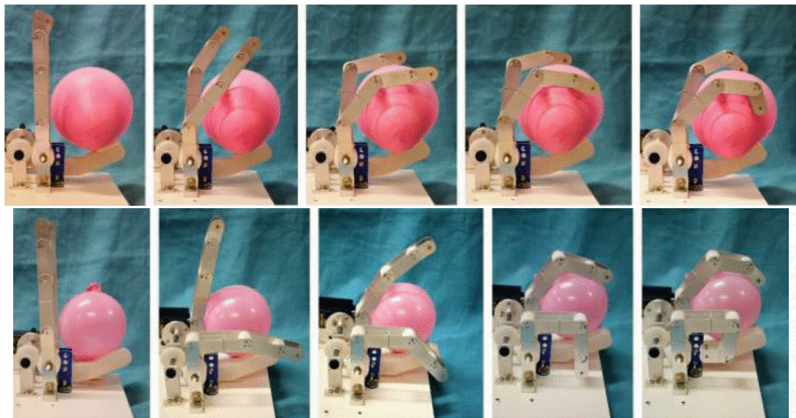
Sensors

EMG control systems

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Grasping object with 2 fingers (upper line)
and 1 finger (bottom line). [7]



EMG control system

Feature Extraction

Motivation

Sensors

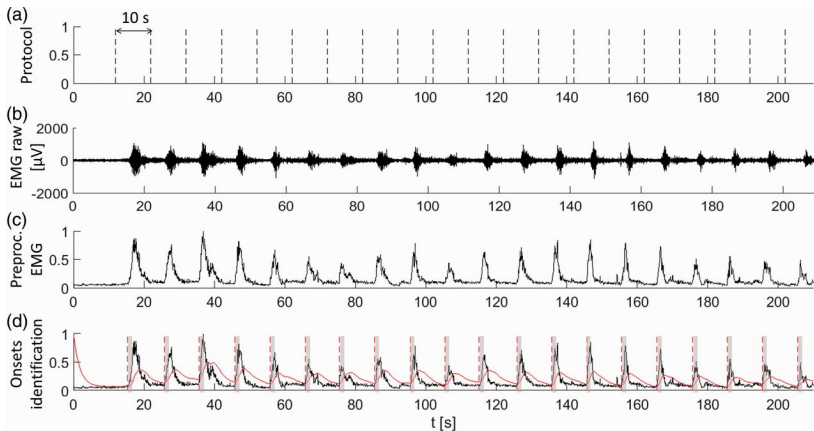
EMG control systems

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Red lines = mean values with applied low-pass filter.
Red dashed lines = onset of signal.



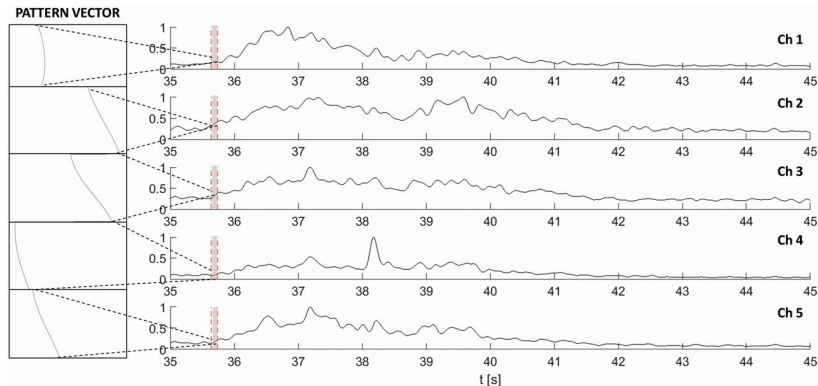
[3]



EMG control system

Classification with ANN

Vectorization of data in experiment of M.Gandolla et al. [3]

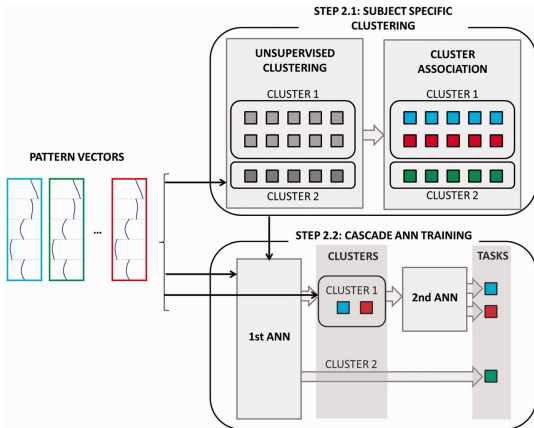


[3]

EMG control system

Classification with ANN

Calibration procedure in experiment of M.Gandolla et al. [3]



[3]



EMG control system

Limitations

Motivation

Sensors

EMG control systems

Feedback

Nice video

References

- ▶ 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.





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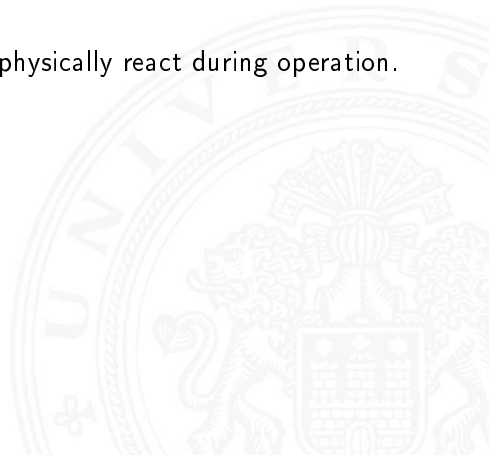
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Feedback

Could device be included into user's body image?

Motivation

Sensors

EMG control systems

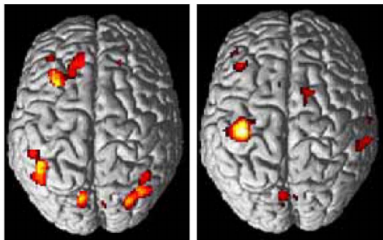
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References

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]

- ▶ 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



Conclusion

Motivation

Sensors

EMG control systems

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Nice video

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Conclusion

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Sensors

EMG control systems

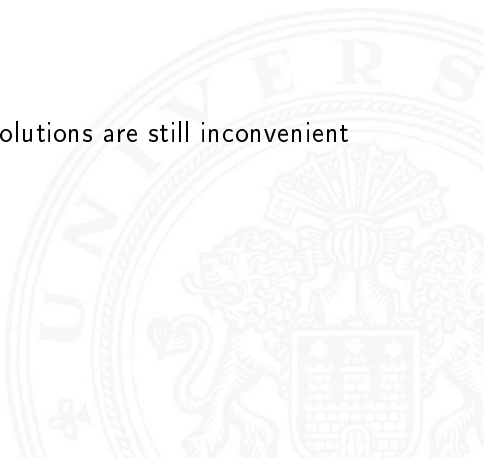
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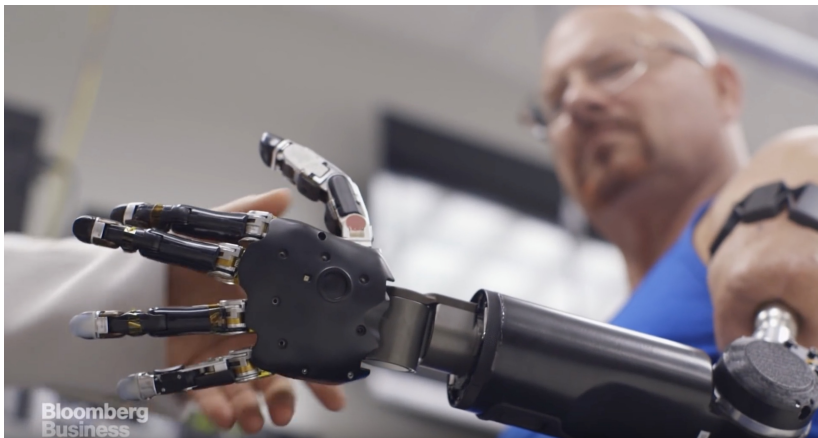
- ▶ Patients are able to return to simple functional activities of daily life.
- ▶ Enhancement with biofeedback helps to prevent phantom pain and neuro reconstruction.

- ▶ Unfortunately, contemporary solutions are still inconvenient



Upper limb prosthesis from John Hopkins University, Applied Physics Laboratory:

<https://www.youtube.com/watch?v=-0srXvOQlu0>



[www.bloomberg.com]



- [1] H. A. Alejandro, R. Kato, H. Yokoi, T. Arai, and T. Ohnishi. An fMRI Study on the Effects of Electrical Stimulation as Biofeedback. In *2006 IEEE/RSJ International Conference on Intelligent Robots and Systems*, pages 4336–4342, Oct. 2006. DOI:10.1109/IRDS.2006.282006.
- [2] M. Asghari Oskoei and H. Hu. Myoelectric control systems—A survey. *Biomedical Signal Processing and Control*, 2(4): 275–294, Oct. 2007. ISSN 1746-8094. DOI:10.1016/j.bspc.2007.07.009. URL <http://www.sciencedirect.com/science/article/pii/S1746809407000547>.

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- [4] M. LeBlanc. Give hope - give a hand, 2011. URL <https://web.stanford.edu/class/engr110/2011/LeBlanc-03a.pdf>.
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DOI:10.1109/BIOROB.2014.6913758.