FRIEDRICH-ALEXANDER UNIVERSITÄT ERLANGEN-NÜRNBERG
FACULTY OF ENGINEERING

Intent detection and somatosensory feedback

#03: Signal Processing

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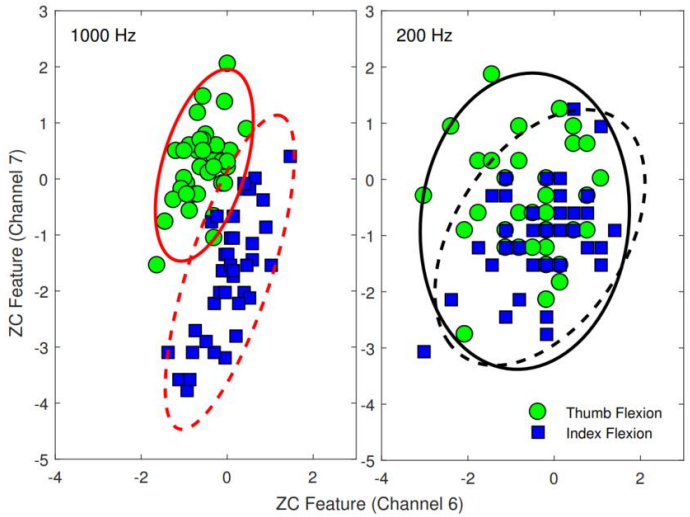


Figure 2. Differences in EMG patterns between using: (**left**) a 1000 Hz sampling rate; and (**right**) a 200 Hz sampling rate. ZC features are extracted from two different EMG channels (6 and 7) during thumb flexion (green circle markers and solid lines) and index flexion (blue square markers and dashed lines). Samples are from Subject 1 of Database 3.

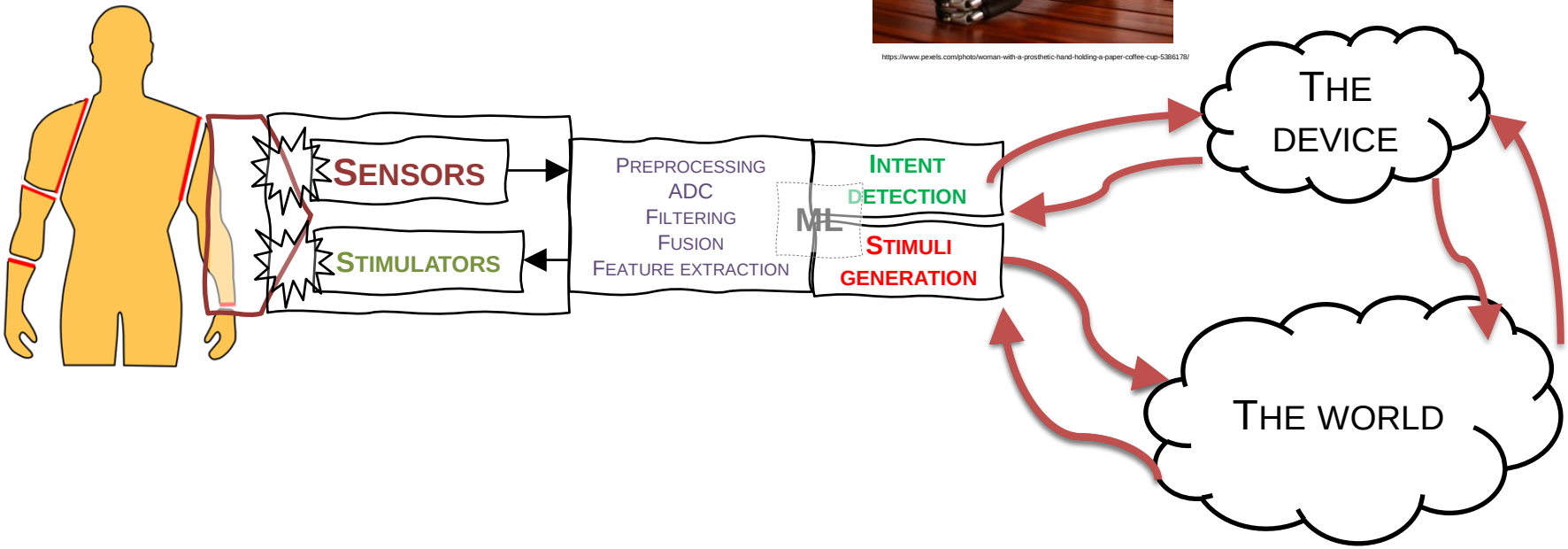
EMG patterns related to two actions. Reproduced from Angkoon Phinyomark, Rami N. Khushaba and Erik Scheme, *Feature Extraction and Selection for Myoelectric Control Based on Wearable EMG Sensors*, MDPI Sensors 2018, 18, 1615

The *rubber hand illusion.* See Botvinick M, Cohen J., *Rubber hands 'feel' touch that eyes see.* Nature. 1998 Feb 19;391(6669):756. doi: 10.1038/35784. PMID: 9486643.

Intent detection and somatosensory feedback

HMIs for the disabled

https://www.pexels.com/photo/woman-with-a-prosthetic-hand-holding-a-paper-coffee-cup-5386178/



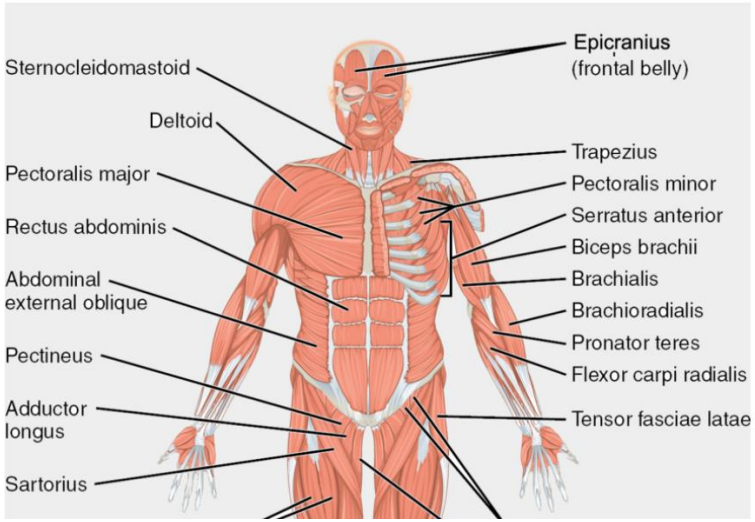
Where to measure

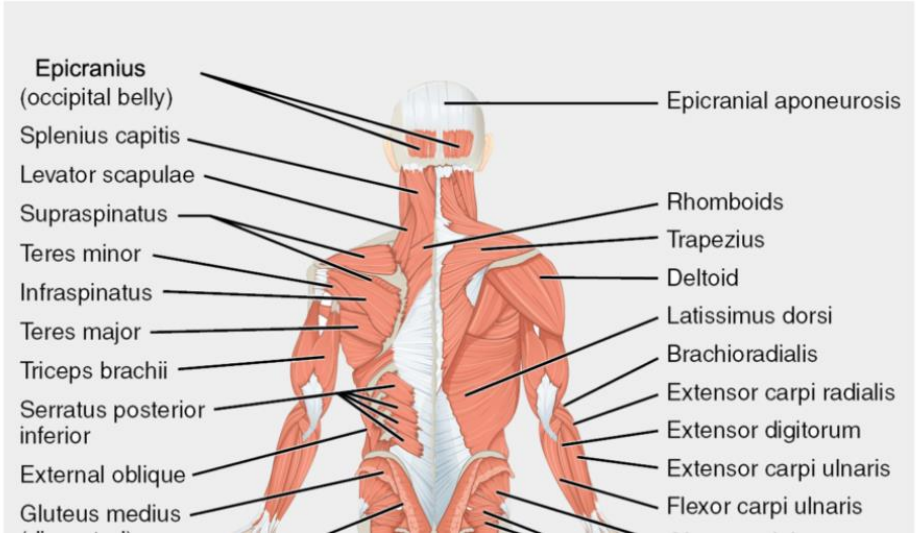
Example for following Exercises

A scientist plans to recorded sEMG signals of wrist motions like pronation, supination, flexion, extension, etc..

Questions:

Where would you place the sEMG sensors?
What would be a desired measurement rate?





https://courses.lumenlearning.com/ap1x94x1

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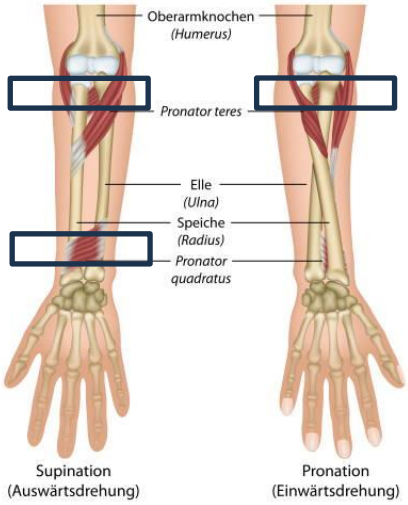
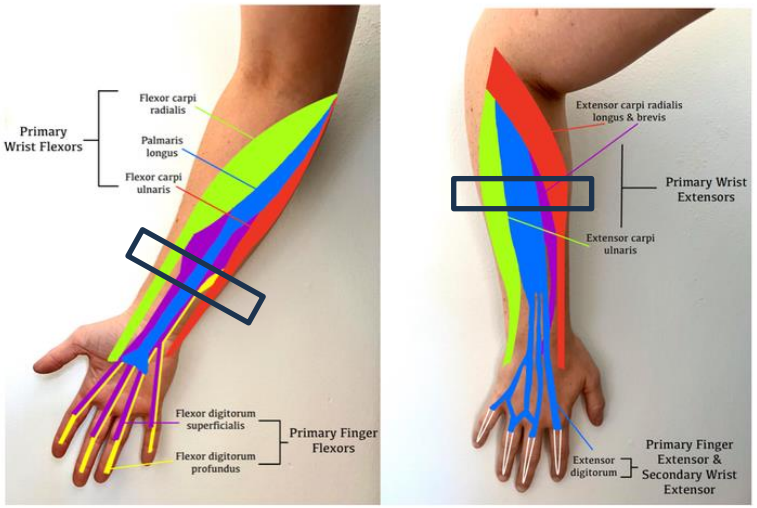


https://gelenk-klinik.de/orthopaedie-glossar/pronation.html



*images not drawn to scale

https://www.climbing.com/skills/wrist-strengthening-rehab-climbers/

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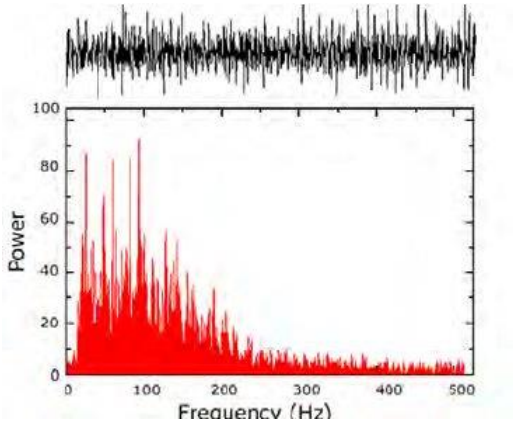

“The frequency of an EMG signal is between 0 to 500 Hz.
However, the usable energy of EMG signal is dominant between 50-150 Hz.”

Shaw, Laxmi & Bhaga, Sangeeta. (2012). Online EMG Signal Analysis for diagnosis of Neuromuscular diseases by using PCA and PNN.. International Journal Of Engineering Science and Technology 0975-5462. 4. 4453-4459.

Transmission

Example for following Exercises

A scientist plans to recorded sEMG signals from a participant's forearm in order to train a machine learning method for prosthesis control. For the data acquisition a Myo Armband (Thalmic Labs) with 8 channels around the forearm was used. Transmission of sEMG is planned to be wireless through Bluetooth 4.0. During the experiment data will be gathered for 5 seconds for the movements *Flexion*, *Extension* and *Rest*.

Further info:

Sampling frequency: 200 Hz
Channels: 8
Range: 1…256
Bluetooth 4.0 data throughput: 0.305 Mbit/s

Questions:

1, Is the Bluetooth connection sufficient for data transmission? Explain.
2, In a second experiment the scientist plans to use high-density sEMG with 128 channels, a 16-bit resolution and a sampling frequency of 2 kHz. Does the scientist need to find another way of data transmission?
3, During the experiment all data is queued up for 15s in a 2D array. How much temporary storage is needed in each scenario?
4, How does it differ if you send the data via TCP/IP or via UDP?
5, What would be a suitable alternative for Bluetooth?

Transmission

Answer

Transmission rate u

System 1:

The necessary rate u for a system with a sampling rate f_s, a resolution r and c number of channels is:

$$u = f_s \cdot c \cdot r$$

$$for\ r = 8\ bit\ (range\ 256)$$

$$u_1 = 12{,}800\ \text{bps} = 12{,}8\ \text{kbps} = 0.0128\ \text{Mbps}$$

System 2:

$$u_2 = f_s \cdot c \cdot r = 4096\ \text{kbpB} = 4.096\ \text{Mbps}$$

Storage occupation s

For $t = 15\ s$

$$s = f_s \cdot c \cdot r \cdot t = u \cdot t$$

$$s_1 = 0.192\ \text{Mbit} = 0.024\ \text{Mb}$$

$$s_2 = 61.44\ \text{Mbit} = 7.68\ \text{Mb}$$

Eigenvalues & Eigenvectors

Questions

After the data acquisition the scientist rectifies the data and afterwards runs it through a lowpass Butterworth filter. Later that day the scientist would like to get a first impression how differentiable the single movements are. The scientist decides to start with a PCA to visually inspect the data.

Channel 1	Channel 2	Channel 3	Channel 4	Channel 5	Channel 6	Channel 7	Channel 8
0,0366	0,0220	0,0185	0,0331	0,0255	0,1047	0,0573	0,0842
0,0530	0,0283	0,0223	0,0364	0,0373	0,1456	0,0846	0,1259
0,0722	0,0383	0,0265	0,0417	0,0501	0,1845	0,1176	0,1700
0,0911	0,0492	0,0305	0,0473	0,0612	0,2238	0,1492	0,2115
0,1064	0,0591	0,0335	0,0527	0,0718	0,2559	0,1757	0,2507
0,1191	0,0683	0,0357	0,0568	0,0801	0,2823	0,2046	0,2927
0,1288	0,0758	0,0373	0,0606	0,0849	0,2993	0,2383	0,3338
0,1361	0,0817	0,0386	0,0648	0,0900	0,3099	0,2736	0,3699
0,1406	0,0869	0,0398	0,0678	0,0959	0,3192	0,3062	0,4039
0,1424	0,0902	0,0403	0,0698	0,1011	0,3231	0,3318	0,4278

Provide the formula for standardization and covariance matrix calculation, then simplify. Afterwards, calculate both exemplarily on 10 data points of 2 sEMG channels lying on flexor (channel 4) and extensor (channel 8) muscles.

$$ {}_4\overline{x} = 0.0531 \qquad {}_4\sigma = 0.0131\,; $$
$$ {}_8\overline{x} = 0.2670 \qquad {}_8\sigma = 0.1185 $$

Info: Following data was subsampled after filtering, leaving 12,5% of the original data i.e. 10 data points = 0.8 s

Eigenvalues & Eigenvectors

Answer

Standardization $x_{ij,new} = \frac{x_{i,j} - {}_j\overline{x}}{\sigma}$

Covariance two features/channels $\sigma\left({}_4\boldsymbol{x}, {}_8\boldsymbol{x}\right) = \frac{\sum\left({}_4x_i - {}_4\overline{x}\right)\left({}_8x_i - {}_8\overline{x}\right)}{N-1} = \frac{\sum\left({}_1x_i \;\; {}_2\overline{x}\right)}{N-1}$

Channel 1	Channel 2	Channel 3	Channel 4	Channel 5	Channel 6	Channel 7	Channel 8
- 1,7374	- 1,5412	- 1,8057	- 1,5252	- 1,7317	- 1,8099	- 1,4596	- 1,5429
- 1,3066	- 1,2863	- 1,3087	- 1,2731	- 1,2709	- 1,2814	- 1,1683	- 1,1911
- 0,8018	- 0,8794	- 0,7613	- 0,8727	- 0,7700	- 0,7799	- 0,8147	- 0,8188
- 0,3024	- 0,4377	- 0,2351	- 0,4453	- 0,3352	- 0,2711	- 0,4771	- 0,4687
0,0997	- 0,0367	0,1572	- 0,0277	0,0794	0,1425	- 0,1946	- 0,1377
0,4341	0,3380	0,4438	0,2809	0,4039	0,4842	0,1145	0,2165
0,6889	0,6416	0,6564	0,5717	0,5902	0,7037	0,4742	0,5636
0,8811	0,8815	0,8275	0,8912	0,7893	0,8400	0,8516	0,8676
0,9986	1,0916	0,9760	1,1248	1,0218	0,9611	1,2003	1,1550
1,0458	1,2285	1,0499	1,2756	1,2231	1,0107	1,4737	1,3566

Covariance matrix

$$\begin{pmatrix} \mathbf{1} & \mathbf{0.9981} \\ \mathbf{0.9981} & \mathbf{1} \end{pmatrix}$$

Sensor Fusion

Questions

Imagine you acquired data with EMG and IMUs during an experiment.

1. What issues might occur during sensor fusion?
2. How could you handle different sampling rates?
3. How could you handle differences in the timestamps?
4. How could you handle missing pieces of data?

https://www.lp-research.com/lpmocap/

https://mindrove.com/product/armband_8_ch/

Sensor Fusion

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4. How could you handle missing pieces of data?

Answer

1. E. g. different sampling rates, shifts in timestamp (and many more)
2. Multiple approaches are possible: leave it like it is, get the same sampling rate, etc.
3. There are many ways, one would be that you have some initial sequence which you can distinguish as a starting point (e. g. put the hand up and make a power grasp, once you leave the position, the experiment will start)
4. If it is not required, leave it out, if it is required interpolate