Artifact Reduction Algorithm

This section deals with the problem of rejecting motion artifacts from sEMG signals which can detrimentally affect the detection of muscular activation and pattern recognition procedures during dynamic contractions. Due to the electric characteristics of motion artifacts (located in the lower frequencies) high-pass filtering has been presented as the most immediate solution. However, extrinsic mechanical disturbances induced by rapid limb movements can lead to interfering artifacts that eminently overlap the sEMG signal's frequency spectrum.

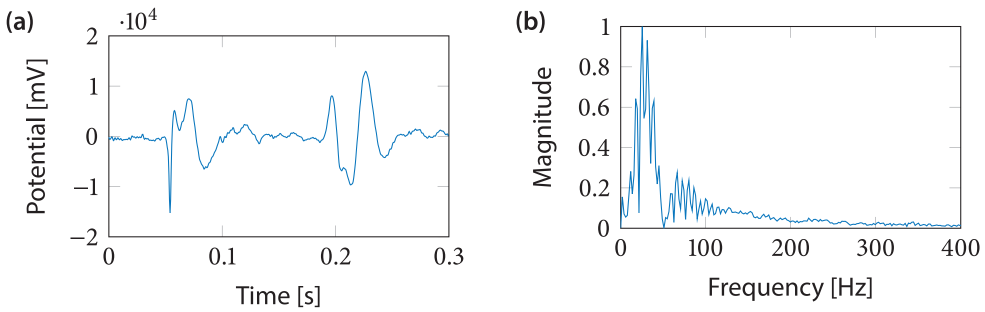

Figure 1: Mechanical disturbance in sEMG signal due to rapid movement, in absence of muscular contraction.

Wavelet transform based method

A stationary wavelet transform based method to reduce artifacts from dy-namic sEMG signals is presented:

Step 1: Signal Separation It can be seen that mechanical disturbances provoke spatially correlated artifacts at different electrode sites during multichannel sEMG signal acquisition. Signal separation techniques could therefore be utilized to create a subspace, in which the artifact should be pooled in fewer components, which in turn can be beneficial for artifact detection and removal. Different ICA techniques (see Table 1) and PCA are evaluated for that reason.

Table 1: Implementations of different ICA algorithms.

Name	Toolbox
FastICA	The FastICA package Version 2.5
TDSEP	TDSEP ICA tools Version 2.01
JADE	jadeR Version 1.9

Step 2: SWT Decomposition The principle or independent components are decomposed by means of SWT yielding a time-scale representation, which can be used for the temporal detection of disturbances in the signal. Daubechies 1 (db1) wavelets are used in a first attempt to increase computation speed of a fourth level SWT decomposition. SWT is preferred due to its time-invariant nature as this can play a crucial role in artifact detection.

Step 3: Thresholding Having a 2000 Hz sampled signal, the approximation level corresponds to a frequency range between 0–62.5 Hz, while the third detail's subband frequencies in the range of 125–250 Hz contains the highest frequency components of the myoelectric signal. Hence, artifact free sEMG data is represented by high values in the third details and lower valued approximation coefficients. This motivated the set up of an artifact detection threshold thr as follows:

$$thr_k = \text{median}(|cD_3|) + k \cdot \sigma(cD_3), \tag{1.1}$$

where cD_3 are all detailed coefficients in the third level, σ is the standard deviation of these coefficients and k is a parameter which allows level dependent threshold adjustment. All approximation coefficients exceeding thr are considered as belonging to an artifact and hard thresholding is applied:

$$cA_s = \begin{cases} 0, & \text{if } cA_s > thr_1 \\ cA_s, & \text{otherwise} \end{cases} \tag{1.2}$$

where $s \in [1, N]$ denotes the location of the coefficient within the time window of sample length N.

As depicted in Figure 1 artifacts can contain frequency components higher than the frequencies that are represented by the approximation coefficients of a fourth level decomposition. The coefficient thresholding has consequently be extended to the detail coefficients at the n-th level $cD_{n,s}$:

$$cD_{n,s} = \begin{cases} 0, & \text{if } cD_{n,s} > thr_0 \vee cA_s > thr_1 \\ cD_{n,s}, & \text{otherwise} \end{cases} \tag{1.3}$$

where $n = 1, 2, 3$ and 4 and k is set to 0. In order to restore EMG derived components within the exceeding coefficients, the detailed coefficients can be set to a level and sign dependent median value. This approach intends to lower the affect on feature space of the EMG signal after coefficient shrinking and can be written as:

$$cD_{n,s} = \begin{cases} \operatorname{sgn}(cD_{n,s}) \cdot \operatorname{median}(|cD_n|), & \text{if } cD_{n,s} > thr_0 \vee cA_s > thr_1 \\ cD_{n,s}, & \text{otherwise.} \end{cases} \tag{1.4}$$

Step 4: Signal Reconstruction ISWT is applied to the modified coefficients and inverse ICA respectively inverse PCA is applied afterwards to reconstruct the artifact free sEMG signals.

$$cD_{n,s} = \begin{cases} \operatorname{sgn}(cD_{n,s}) \cdot \operatorname{median}(|cD_n|), & \text{if } cD_{n,s} > thr_0 \vee cA_s > thr_1 \\ cD_{n,s}, & \text{otherwise.} \end{cases} \tag{1.4}$$