Detection of Neuromuscular Diseases
Using Surface Electromyograms

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Surface EMG generation process
Detection of Neuromuscular Diseases Using Surface Electromyograms
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motor neuron

Spinal Cord

neuromuscular junctions

muscle fibers

tendon region
Detection of Neuromuscular Diseases Using Surface Electromyograms

- Spinal Cord
- Motor neuron
- Single fiber action potentials
- Motor unit action potential (MUAP)
- Muscle fibers
- Neuromuscular junctions
- Tendon region
Classification of Neuromuscular Disorders
Motivation

Using SEMG in the clinical diagnosis the classification to normal, myopathic and neuropathic groups of subjects can be achieved.

Neuromuscular disorders:

- myopathy - dysfunction of muscle fibres
- neuropathy - damage to the peripheral nervous system, which transmits information from the brain and spinal cord to every other part of the body
Why SEMG?

- Non invasive
- Voluntary stimulation
- User friendly
- Can be applied with the same ease on children, adults, patients
- No need for medical supervision
- Can be used nearly on any extremity muscle with minor modification
Previously used methods

- **needle EMG techniques:**
  - analysis of individual MUAPs (amplitude, duration),
  - turns–amplitude analyses,
  - analysis of the firing rate of MU,
  - power spectrum analysis,...

- **surface EMG techniques:**
  - turns and zero-crossings per second,
  - median frequency and total power per second,
  - bispectrum peak amplitude,
  - higher order statistics,...
Data acquisition

- 19 normal, 11 myopathic and 9 neuropathic subjects with the gender and age matching between normal and patient groups
- left biceps brachii muscle was examined
- four-bar SEMG active probe with an interelectrode distance of 10 mm and a bar width of 1 mm was used
- single differential recordings were recorded, one from each pair of the electrode bars
- recordings were performed for 5 seconds at 10, 30, 50, 70 and 100% of the MVC
- two trials at each force level were performed,
- band-pass filter [20÷500 Hz] was initially applied on the recorded signals that were then sampled with a sampling frequency of 1000 Hz at a 12-bit resolution.
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Raw SEMG signals

1st electrode

Channel

Time (s)

0.75 0.8 0.85 0.9 0.95

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Raw SEMG signals

Level of contraction (%MVC)

Time (s)
Feature extraction

The recorded signals were further processed in order to extract some important features from them to be used in the classification process.

- totally 10 signals per person,
- each of them was transformed using continuous wavelet transform,
- diadic Haar wavelet was chosen and each signal was transformed at 8 different scales \(2^j, j = 1, 2, \ldots, 8\).
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Continuous wavelet transform

\[ C_{a,b} = \int_{-\infty}^{+\infty} s(t) \frac{1}{\sqrt{a}} \psi \left( \frac{t - b}{a} \right) \, dt \]
Feature extraction – step 2

- At each scale, the Shannon entropy is calculated on transformed signal:

\[ H(X) = - \sum_i P(X = a_i) \log P(X = a_i) \]

- Entropies of all signals have to be computed on the same interval subdivisions.
- Range of SEMG amplitude was [−0.4, 0.4]
- The interval was divided in 100 equally sized bins.
- Number of samples falling in each bin was counted for each signal (histogram).
- Probability of bin is calculated as ratio of number of samples in a bin to number of all samples.
A set of 80 scalar features per subject was formed, which were base for the classification of subjects.
Classifications to the following decision classes were performed:

- normal / abnormal (myopathic and neuropathic),
- normal / myopathic,
- normal / neuropathic,
- myopathic / neuropathic,
- normal / myopathic / neuropathic.

5 different techniques from the WEKA machine learning package were used:

- decision trees j48,
- random trees,
- random decision forests,
- support vector machines (SVM),
- ensemble of support vector machine with polynomial kernel.
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Results

- Resulting classifiers were obtained using 3-fold cross validation with 50 iterations for every machine learning technique.
- SVM and SVM ensemble performed the best, although decision trees with human readable knowledge representation were only slightly less accurate.
- Since datasets decision classes are biased, we applied the receiver operator characteristic (ROC) to measure the classifier quality.
## Results

<table>
<thead>
<tr>
<th>Decision classes</th>
<th>No. of classes</th>
<th>Number of subjects per class</th>
<th>Classification accuracy(standard deviation)[%]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Decision trees j48</td>
</tr>
<tr>
<td>normal/abnormal</td>
<td>2</td>
<td>24 / 15</td>
<td>56.36(8.80)</td>
</tr>
<tr>
<td>normal/myopathic</td>
<td>2</td>
<td>22 / 8</td>
<td>68.69(11.20)</td>
</tr>
<tr>
<td>normal/neuropathic</td>
<td>2</td>
<td>21 / 7</td>
<td>73.52(11.19)</td>
</tr>
<tr>
<td>myopathic/neuropathic</td>
<td>2</td>
<td>8 / 7</td>
<td>48.67(19.17)</td>
</tr>
<tr>
<td>normal/myopathic/neuropathic</td>
<td>3</td>
<td>24 / 8 / 7</td>
<td>51.69(11.06)</td>
</tr>
</tbody>
</table>
Conclusion

- The SEMG signals in patients with the neuromuscular diseases can vary evidently depending on the stage of the disease.
- SEMG-based diagnosing is not enough, other tests, such as muscle biopsies, blood tests, or genetic testing, should also be carried out.
- Myopathy can affect only individual muscles, while the properties of other muscle can remain unchanged.
- Since SEMG measures the superimposed electrical activity of all the MUs under surface electrodes, the deviating MUs can be hidden among healthy ones.
- Method could be improved using an appropriate decomposition technique to extract individual MUAPs from the SEMG.