Extraction of Typical Features from Surface EMG Signals in Parkinson's Disease

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Introduction

- A typical surface electromyogram (EMG) of a patient with Parkinson's disease (PD) has an increased tonic background activity and an alternating pattern of EMG bursts (Fig. 1).

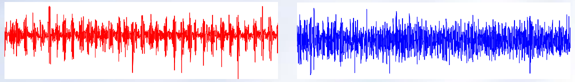

Fig 1. Surface EMG (biceps brachii) of a patient with PD (left) and a healthy young female (right) during isometric contraction without any loading.

- The aim of this study is to extract typical features from Parkinsonian EMG signals by calculating specific EMG parameters and examining them with the help of principal components.

Methods

- Feature extraction from surface EMG signals is performed in three stages:

1. Calculation of variables = features

- Following EMG variables were chosen for analysis based on their potential suitability for characterizing Parkinsonian EMG signals:
  - k = kurtosis of EMG sample data
  - bf = average frequency of bursting
  - cr = height / width of crossing rate expansion
  - REC = recurrence rate of EMG (RQA)
  - DET = determinism of EMG (RQA)
  - $D2$ = correlation dimension

2. Feature vectors

- Feature vectors $\mathbf{z}$ are formed of sequentially placed and normalized EMG parameters:

$$\mathbf{z} = (\, k_r \;\; k_l \;\; bf_r \;\; bf_l \;\; cr_r \;\; cr_l \;\; REC_r \;\; REC_l \;\; DET_r \;\; DET_l \;\; D2_r \;\; D2_l \,)^T$$

where sub indexes r and l denote the right and the left side of the body respectively.

3. Principal component representation

- Feature vectors $\mathbf{z}$ can be decomposed into orthogonal basis vectors $\mathbf{x}_i$. That is, they can be presented as a weighted sum of basis vectors.

$$\mathbf{z} = w_1\mathbf{x}_1 + w_2\mathbf{x}_2 + \ldots + w_p\mathbf{x}_p$$

The weights w_i are called principal components.

- There are many ways to select the basis vectors. In this study, the basis vectors were selected from experimental EMG data. The feature vectors $\mathbf{z}_i$ for M subjects were placed as column vectors in data matrix $\mathbf{Z}$

$$\mathbf{Z} = (\, \mathbf{z}_1 \;\; \mathbf{z}_2 \;\; \ldots \;\; \mathbf{z}_M \,).$$

- After which, the basis vectors were obtained as the eigenvectors of data correlation matrix

$$\mathbf{R}_z = \mathbf{Z}\mathbf{Z}^T / M.$$

- Principal components can be solved for any EMG feature vector as a least square solution.
- A set of EMG parameters forming the feature vectors can be compared between subjects by comparing the principal components.

Results

- Biceps brachii EMG signals measured from 45 patients with PD (on-medication) and 56 healthy controls were examined in this study.
- The signals were measured during isometric constant force contraction without any loading (Fig. 2).
- Seven-seconds long segments of EMG signal were chosen for analysis and detrended by smoothness priors method.
- EMG features and feature vectors were calculated as described in the methods section.

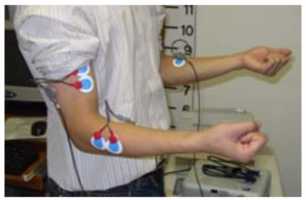

Fig. 2. EMG measurement protocol and ME6000 -measurement unit (Mega Electronics Ltd.).

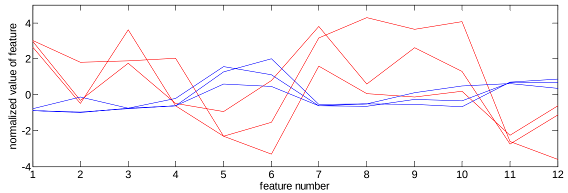

Fig. 3. Feature vectors for three patients (red) and three healthy controls (blue).

- The difference between the feature vectors of three patients and three healthy controls is clearly seen in Fig. 3.
- This difference can also be assessed by comparing principal components (especially the first w_1 and the second w_2 principal component).
- The values of w_2 with respect to w_1 for the examined 45 patients and 56 healthy controls are represented in Fig. 4.
- One can see in Fig. 4 that the principal components are able to discriminate EMGs of patients with PD from EMGs of healthy controls.

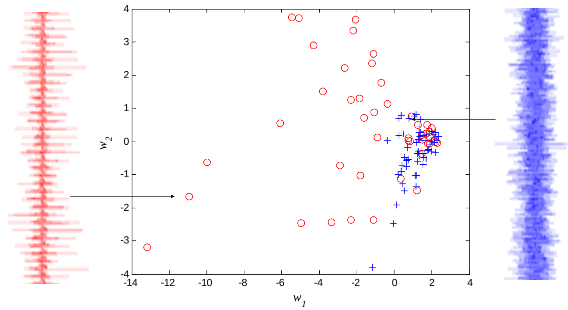

Fig. 4. The second principal component w_2 with respect to the first principal component w_1 of 45 patients with PD (o) and 56 healthy controls (+).

Conclusions

- A combined analysis of EMG signal morphology and nonlinear characteristics is a potential method for extracting typical PD related bursting features from EMG signals.
- The method used was able to discriminate EMGs of patients with PD from EMGs of healthy controls.

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