Classification of single trial EEG: A comparison of different parameters

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Abstract: EEG signals were recorded from electrode positions C3 and C4 while subjects were performing right and left index finger movements. The single trial signals were classified using linear discriminant analysis and a neural network (Learning Vector Quantization). Several parameter estimation methods were compared across three subjects. The results of classification are reported and different methods were compared.

Key words: EEG analysis, Single trial, Barlow- Hilbert- Hjorth parameters, adaptive autoregressive parameters, Linear Discriminant Analysis, Learning Vector Quantization, Inter-subject variability

1 Introduction

An important aspect for the realization of an EEG based Brain Computer Interface (BCI) is the on-line analysis of spatio-temporal EEG pattern. These patterns from one or more EEG channels are obtained from estimation methods on single trial bases.
On this challenge several difficulties have to be taken into account:

- The Inter-trial variability,
- the Inter-individual variability,
- Limitation of the method used for feature extraction,

These EEG patterns are assigned to different brain state using some classification method.
In this work several methods were compared across several subjects, to find out which parameters are most appropriate for single trial EEG analysis.

2 Material and Methods

EEG data derived from C3 and C4 of three subjects, performing self-paced left and right hand finger movement, were used. The data was divided into trials with 9s length, where movement onset occurred at second 5. After visual artifact removal the number of trials of left and right hand movement was 41-50, 57-42 and 53-35 for the subjects E08, E10 and E15 respectively.

The following parameters were compared:

(a) faBarlow: the mean amplitude, mean frequency a the spectral purity [2] of with 5-15 Hz filtered EEG signal
(b) faHjorth: Activity, Mobility and Complexity [3] of with 5-15 Hz filtered EEG signal
(c) faHilbert: The Envelope and frequency [5] of with 5-15 Hz filtered EEG signal
(d) Band a: The power of the band 10-13 Hz of the EEG signal
(e) CoDe a: Amplitude and Phase of the band 10-13Hz using Complex Demodulation [6]
(f) YAR: The Autoregressive (AR) parameters estimated with the Yule-Walker approach [6] using a model order of 6.
(g) BAR: The Autoregressive parameters estimated with the Burg approach [4] using a model order of 6.
(h) AAR: Here the parameter was calculated continuously using the method of Schack et al. [7] and [8] from the beginning of every trial. For the classification the average values from second 4-5 were used. An adaptive AR(6)-model, equals ARMA(6,0), was used.
(i) Opt_B t1: First the most deciding frequency components were determined for every subject. The power values of this frequency band were used
(j) Opt_B t4: Same as Opt_B t1, but the band power values of 4 segments of 0.25 s length, were used.

The parameters (a)-(g) and (i) were estimated from second 4-5, (h) is an adaptive method starting with second 0 at every trial and (j) uses 4 segments during second 4-5. For the classification Linear Discriminant Analysis (LDA) and Learning Vector Quantization (LVQ) [1], both were 10 x 10 fold crossvalidated, were used.

3 Results

	LDA			LVQ		
Subject	**E08**	**E10**	**E15**	**E08**	**E10**	**E15**
faBarlow	12.52	11.99	27.54	13.40	17.30	28.90
faHjorth	12.67	13.16	22.93	13.20	14.50	26.80
faHilbert	13.31	14.14	35.39	14.90	15.70	34.60
Band a	26.08	13.71	27.22	23.30	9.60	29.30
Co-De a	24.32	12.21	28.03	25.40	9.70	24.30
YAR	16.29	18.36	20.03	28.89	16.36	34.99
BAR	14.60	13.02	23.28	24.01	11.95	32.33
AAR	12.78	13.78	15.32	24.25	21.73	23.23
Opt_B t1	20.06	16.27	20.11	16.88	14.54	25.50
Opt_B t4	19.30	19.40	26.25	14.41	14.54	26.97

Table 1: Error rate in % using different EEG parameters of C3 and C4. The classes are left and right hand finger movement. The given error rate is the average of a 10x10 crossvalidation.

4 Discussion

Till now, the method Opt_B t4 combined with LVQ was used for the classification in the Graz BCI. One can see that the data from E08 and E10 giving good classification results, whereas E15 giving poor results.

One can see that the result error rate of the classification can be reduced with LDA when using the Hjorth parameters of the alpha wave (5-15 Hz) or AR(6) parameters estimated with the Burg method.

With the adaptive AR parameter the classification result improves significantly also for E15. One reason could be that also data before second 4-5 has some influence on the parameter.

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6 References

[1] Flotzinger, D., Pfurtscheller, G., Neuper, Ch., Berger, J. and Mohl, W. (1994) Classification of non-averaged EEG data by learning vector quantisation and the influence of signal preprocessing. *Medical & Biological Engineering & Computing*, 32: 571-576.

[2] Goncharova, I.I. and Barlow, J.S. (1990) Changes in EEG mean frequency and spectral purity during spontaneous alpha blocking. *Electroenceph. clin. Neurophysiol.*, 76: 197-204.

[3] Hjorth, B. (1970) EEG analysis based on time domain parameters. *Electroenceph. clin. Neurophysiol.*, 29: 306-310.

[4] Kay, S.M. (1988) *Modern spectral estimation: theory and application.* Prentice Hall, New York.

[5] Medl, A., Flotzinger, D. and Pfurtscheller, G. (1992) Hilbert-Transform Based Predictions of Hand Movement from EEG Measurements. *Proceedings of the 14th Annual International Conference of the IEEE Engineering in Medicine and Biology Society*. Paris, France, Oct. 29 - Nov. 1, 1992, 2539-2540.

[6] Priestley, M.B. (1981) *Spectral Analysis and Time Series*. Academic Press, London.

[7] Schack, B., Witte, H. and Grießbach, G. (1993) Parametrische Methoden der dynamischen Spektralanalyse und ihre Anwendung in der Biosignalanalyse. *Biomedizinische Technik*, 38: 79-80.

[8] Schlögl, A. (1995) Timevarying Autoregressive Models with Application to the EEG. MSc-Thesis, University of Technology, Graz.