SINGLE-TRIAL EEG ANALYSIS USING AN ADAPTIVE AUTOREGRESSIVE MODEL

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INTRODUCTION

An important aspect for the realization of a Brain-Computer Interface (BCI) is the analysis of spatio-temporal EEG patterns. Features have to be extracted, which represent the state of the brain. In other words, the differences of the brain-state for different mental processes should be derived. In the research work presented here, the different processes are preparations for left and right finger movement. These should be represented in different brain states. Several effects make it difficult to identify differences of the brain-state. These are:

- the Inter-trial variability,
  the brain state is build up by multiple processes, but only the process preparing the movement is of interest
- Inter-individual variability,
  the brain processes between subjects and/or sessions are not identical.
- Limitation of the method used for feature extraction,
  the evaluation methods have to be applied across trials and across several subjects;
  a method is superior to others if the error rate across different subjects is low.

This analysis has to be made on single EEG trials and can be based on the assumption of stationary or time-varying models. In the first case segmentation methods can be used. Features can be extracted from every segment. For Autoregressive (AR) models, the parameters can be estimated using the Yule-Walker or the Burg method (Wei, 1990). In the latter case, an adaptive model has to be used. An simple approach for Adaptive Autroregressive models was proposed by Schack et al. (1993). It is also known as (normalized) Least-Mean-Square (LMS) method.

METHOD

The EEG Signal Y_t is described by the adaptive autoregressive model:

$$Y(t) = a_1(t)Y(t-1) + a_2(t)Y(t-2) + \ldots + a_p(t)Y(t-p) + X(t)$$

The parameters obtained from two or more electrodes form an N-dimensional feature vector for on-line classification of EEG patterns related to different brain states. For the evaluation, a Linear Discriminant Analysis (LDA) with 10-fold cross-validation was used. To set up such a classifier, a large number of examples from each brain state is needed. In this report, EEG data from three subjects are analyzed by AR and AAR models of order p=6.

AAR parameters were estimated adaptively using an LMS algorithm (Schack et al. 1993) for every channel as follows:

$$E(t) = Y(t) - a_1(t)Y(t-1) - \ldots - a_p(t)Y(t-p)$$

$$a_k(t+1) = a_k(t) + cE(t)Y(t-k)$$

$$\text{where } c = f \,/\, \mathrm{var}\{Y\}$$

The results were compared with AR parameters estimated from segments 1 sec prior to movement on-set using the Yule-Walker and the Burg Method. Furthermore the variance of the error process and of the EEG signal was used as an additional feature (Schloegl 1995).

RESULTS

The monopolarly recorded EEG data are preprocessed using the Laplace-Operator. The data analyzed are trials of 9 sec recorded from electrodes overlaying the sensorimotor area of both hemispheres. The subjects carried out a voluntary left or right finger movement. The time-constant and frequency band used for EEG recording were T=0,3 sec and fu=40Hz. The data were sampled with 128 Hz; the trials were synchronized with movement on-set at 5 sec. The data sets from three subjects (E08, E10 and E15) consist of 50, 42, 35 trials for right finger movement and 41, 57 and 53 trials for the left side. The DC part of the EEG signals was removed using a Blackman-128 Window (<2Hz).

Method	E08	E10	E15
AAR-6-LMS	12.78	13.78	15.32
AAR-E6-LMS	12.00	9.17	17.14
AAR-Y6-LMS	12.68	8.97	14.53
AR-6-B	14.60	13.02	23.28
AR-6-YW	16.29	18.36	20.03
AR-E6-B	13.84	11.10	24.64
AR-E6-YW	18.71	12.81	20.69

Table 1: **Error rate using the parameters calculated with every method and for the subjects E08, E10 and E15. The parameters were calculated from C3 and C4 before movement onset. The classification task was to distinguish between left and right index finger movement. The parameters were classified with Linear Discriminant Analysis and 10-fold cross-validation. (LMS: Least Mean Square method, B: Burg algorithm, YW: Yule-Walker, 6: 6 AR parameters as classifier, E6: 6 AR parameters + variance of error process, Y6: 6 AR parameters + variance of signal)**

In Table 1 is shown that:

- The smallest error rate obtained for the subjects E08, E10, E15 was 12%, 9% and 15% repectively
- Even for the one subject (E15) with generally poor classification, the best error rate lies at about 15%.
- The error rate across different subjects of the AAR method is more stable
- Generally the AAR parameters give better results compared to the segmentation methods.

CONCLUSION

It is shown that, when using AR parameters, an adaptive method gives better classification results for a left - right finger movement task. The Adaptive AR parameters represent the differences of brain states better than AR parmaters calculated with segmentation methods.
Another advantage of Adaptive methods is, that the variation of the brain-state can be traced with every sample of the EEG signal. In other words the description of the brain state is not limited due to segmentation.

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REFERENCES

Haykin, S. (1986) *Adaptive Filter Theory*. Prentice Hall, Englewood Cliffs, NJ

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

Schloegl, A. (1995) *Time-varying Autoregressive models with Application to EEG*, MSc.-Thesis, University of Technology, Graz.

Wei, W.W.W. (1990) *Time series analysis. Univariate and multivariate methods.* Addison Wesley, New York.