Adaptive autoregressive parameters used in BCI research.

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An EEG-based BCI system is composed of different components including, an EEG recording, feature extraction and/or classification and online feedback. The system in Tübingen uses slow EEG potentials to control the feedback. In Albany, spectral parameters of the EEG are cumulated and used for on-line feedback. Since the beginning the Graz BCI system has been based on spectral analysis of the EEG in combination with some classifier (see Fig. 1). It is obvious that the subject's ability to learn controlling his/her EEG patterns, does depend on the reliability of the feedback. One of the key components in a BCI system is the extraction of EEG features, best suitable to monitor the dynamics of different brain states.

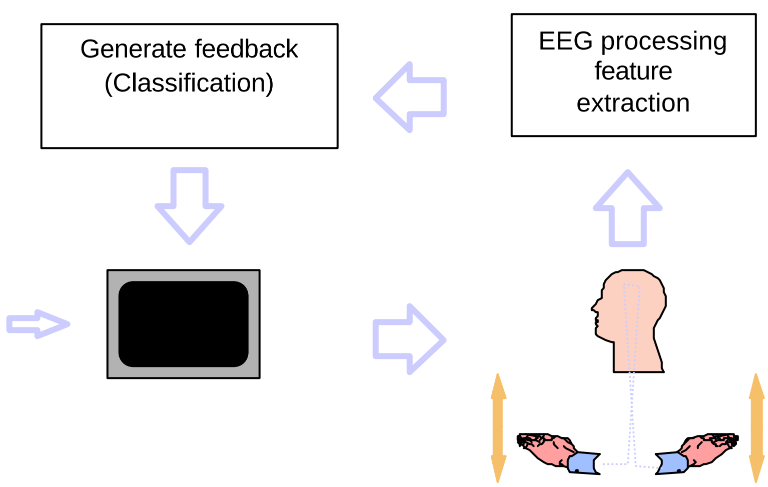

Figure 1: Scheme of an EEG-based Brain Computer Interface with on-line feedback. The EEG is recorded from the head surface, signal processing techniques are used to extract features. These features are classified, the output is displayed on a computer screen. This feedback should help the subject to control its EEG patterns.

For several years, spectral values of certain frequency bands were used as features. Neural networks have been applied for the online and off-line classification. (e.g. Pfurtscheller et al. 1996, Pregenzer et al. 1999, Haselsteiner et al. 2000). Neural networks were also used to search for the optimal electrode position and the optimal frequency band (Pregenzer and Pfurtscheller, 1999, Pfurtscheller et al. 1995). Beside this efforts, attempts to relate the EEG-patterns to the underlying circuitry, the human brain as a biological neural network, were made (Pfurtscheller and Lopes da Silva 1999, Pfurtscheller and Neuper, 2001).
In recent years, Adaptive Autoregressive (AAR) parameters were used as features. AAR parameters have several advantages (Schlögl, 2000): (i) Autoregressive spectra are a

maximum entropy spectral estimator. A limited number of parameters is sufficient to describe spectral properties (i.e. the second order statistics) of the EEG. (ii) The selection of frequency bands is not necessary anymore; (iii) there is a unique optimum solution of AR parameters for describing a given data set. Unlike ARMA and nonlinear models, local optima do not occur. (iv) causal algorithms are available, which means, only data recorded previously are required. (v) efficient algorithms for estimating AAR parameters are available; (vi) linear classifiers have been applied successfully to AAR parameters. (vii) it is possible to provide feedback that's continuous in time and quantity (Schlögl et al. 1997); (viii) AAR parameters provide also a model of the EEG. A measure for the goodness-of-fit is available. Alternative models and model estimates can be compared; (ix) the problems related to the model order an the adaptation of time-frequency-analysis related to the principle of uncertainty as well as problems related to overfitting are addressed.

The advantages of using adaptive autoregressive parameters to generate online feedback are discussed. The AAR parameters should be able to provide the best online-features based on the spectral properties of the EEG.

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