Author's Accepted Manuscript

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www.elsevier.com/locate/sigpro

PII: S0165-1684(16)30187-6
DOI: http://dx.doi.org/10.1016/j.sigpro.2016.08.001
Reference: SIGPRO6228

To appear in: *Signal Processing*

Received date: 12 January 2016
Revised date: 21 July 2016
Accepted date: 1 August 2016

Cite this article as: P. Gonzalez-Navarro, M. Moghadamfalahi, M. Akcakaya anc D. Erdogmus, Spatio-Temporal EEG Models for Brain Interfaces, *Signa Processing,* http://dx.doi.org/10.1016/j.sigpro.2016.08.001

Spatio-Temporal EEG Models for Brain Interfaces

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Abstract

Multichannel electroencephalography (EEG) is widely used in non-invasive brain computer interfaces (BCIs) for user intent inference. EEG can be assumed to be a Gaussian process with unknown mean and autocovariance, and the estimation of parameters is required for BCI inference. However, the relatively high dimensionality of the EEG feature vectors with respect to the number of labeled observations lead to rank deficient covariance matrix estimates. In this manuscript, to overcome ill-conditioned covariance estimation, we propose a structure for the covariance matrices of the multichannel EEG signals. Specifically, we assume that these covariances can be modeled as a Kronecker product of temporal and spatial covariances. Our results over the experimental data collected from the users of a letter-by-letter typing BCI show that with less number of parameter estimations, the system can achieve higher classification accuracies compared to a method that uses full unstructured covariance estimation. Moreover, in order to illustrate that the proposed Kronecker product structure could enable shortening the BCI calibration data collection sessions, using Cramer-Rao bound analysis on simulated data, we demonstrate that a model with structured covariance matrices will achieve the same estimation error as a model with no covariance structure using fewer labeled EEG observations.

Keywords: Structured covariance matrices, Kronecker product, brain computer interface, multichannel electroencephalogram (EEG), auto-regressive (AR) model, linear mixture.

1. Introduction

Electroencephalography (EEG)-based brain computer interfaces (BCIs) offer people with severe speech and physical impairments (SSPI) an alter-