Automated online optimal features selection for an ECoG-based motor Brain-Computer Interface

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Introduction: Motor Brain-computer interfaces (BCIs) create new communication pathways between the brain and the external effectors for severely motor-impaired subjects. The control of complex effectors such as robotic arm or exoskeleton is generally based on real time decoding of high-resolution neural signal. High dimensionality and noise in the brain signal bring challenges to overcome for an online Brain-Computer Interface, such as the decoding model generalization ability and a high computational load. Identification of sparse decoders may allow addressing this problem. Additionally, online closed loop decoder adaptation (CLDA) is known to be efficient procedure for BCI decoders training, allowing taking into account the neuronal feedback. Integration of feature selection directly to the CLDA is potentially beneficial for the system usability, for the decoding performance improvement, and to decrease the computational load during neuroprosthetics use stage. Here, an approach of automated online training of sparse multilinear decoders embedded to CLDA is proposed.

Materials, methods and Results: Sparsity promoting penalization is a common approach to obtain sparse solution. Generally, BCI features are naturally structured and grouped according to spatial (electrodes), frequencies and temporal dimensions. Group-wise sparsity, i.e. the setting to zero the model coefficients within such a group simultaneously, may be beneficial for reducing the computational time/memory and for data transfer. Here, an algorithm for online closed-loop group-wise sparse multilinear decoders training is proposed. Namely, L_p-Penalized Recursive Exponentially Weighted N way Partial Least Square (PREW-NPLS) was explored for three types of sparsity promoting penalization L_p, p = 0, 0.5, 1. The proposed algorithm is a generalization of conventional Recursive Exponentially Weighted N way Partial Least Square (REW-NPLS) algorithm [1] currently employed in "BCI and tetraplegia" clinical trial (NCT02550522, ClinicalTrials.gov) [2], [3]. The algorithms were tested offline in a pseudo-online manner for features grouped in spatial dimension. Epidural ECoG dataset recorded during long-term BCI experiments of virtual avatar control (left / right hand 3D translation) by a tetraplegic was used for comparison study. Novel PREW-NPLS algorithms highlighted comparable or better decoding performance to conventional REW-NPLS, achieved with sparse models. The proposed algorithms are compatible with real time CLDA. The use of penalization requires tuning of the penalization parameter. To solve the problem, a reinforcement learning procedure is proposed to estimate the penalization parameters integrated to CLDA.

Discussion and perspectives: The presented algorithms have been tested in offline, but implemented to process a data stream as if it would have been online experiment. The most promising one still needs to be integrated to be tested in online experiments with a patient. Having such an algorithm performing with high accuracy would allow to have very lightweight decoding software embedded in a small wearable dedicated electronic device.

References

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