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Dynamic Class Balancing for Real-time Decoder Learning

R. Souriau[1], F. Martel[1], T. Aksenova[1]*

[1]*Univ. Grenoble Alpes, CEA, Leti, Clinatec, F-38000 Grenoble, France*

*17 rue des Martyrs, 38054, Grenoble cedex 9, France. E-mail: tetiana.aksenova@cea.fr

Introduction: Real-time BCI decoders training enables taking into account the sensitive responses in the brain neural signals. However, during the training sessions, class imbalance can occur, significantly decreasing the decoder's performance. Class balancing during online streaming model learning is a challenging task as the full training dataset is not available. Moreover, during a session, the experimenter can add new classes/tasks, disrupting class balance. This paper introduces an algorithm for dynamic class balancing during real-time BCI decoder learning, and addressing key BCI requirements: multiclass support, online training, low computational requirements for high-dimensional data.

Material, Methods and Results: This paper proposes the Recursive Sample Weighted – N-way Partial Least Squares (RSW-NPLS) algorithm integrated into a HMM, for dynamic online class balancing during decoder training. The algorithm dynamically tracks the size of classes to compute weights assigned to the training samples at each decoder update. A constraint is applied to avoid large weights. The proposed algorithm is compared in pseudo-online configurations to the generic Recursive Exponentially Weighted – N way Partial Least Squares (REW-NPLS) algorithm using 3 databases from 2 patients. BCI – Exo5, and BCI – Exo8 databases were recorded with a tetraplegic patient (P1) [1] (clinical trial "BCI and Tetraplegia", NCT02550522). BSI – Gait database was recorded in a paraplegic patient (P2) [2] (clinical trial "STIMO-BSI", NCT04632290). Both patients were implanted with two WIMAGINE ECoG recording implants [3] placed in the skull, facing the sensory motor cortex. The patient P2 was also implanted with a spinal cord stimulator to activate his leg muscle groups and restore gait. We consider a 5 states classification problem (right and left hands translation, wrists rotation, idle states) with the database BCI – Exo5. BCI – Exo8 introduces 3 additional classes (right and left grasps, and a walking state). 3 states (left and right hips flexion, idle states) were decoded for the database BSI – Gait. The features were extracted using complex continuous wavelet transform (Morlet) from ECoG recording of 64 channels. The proposed *RSW*-NPLS based HMM outperforms the generic *REW*-NPLS based HMM in term of classification performance (56%, 209%, 18% of improvement for BCI – Exo5. BCI – Exo8, BSI – Gait databases respectively) (Fig.1). The proposed algorithm effectively compensates class imbalance in real-time and maintains high performance, even in case of significant training data imbalance.

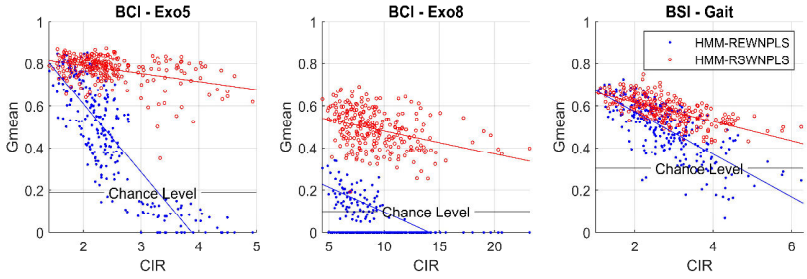

Figure 1: *Gmean performance criterion depending on Class Imbalance Ratio (CIR), the ratio of the majority and the minority class sizes, for 3 databases for the generic REW-NPLS based HMM and the proposed RSW-NPLS based HMM algorithms.*

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