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Towards Calibration-Free ECoG-Based Brain-Computer Interfaces: A Dual-Alignment Incremental Approach

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Introduction: Autonomous usage of ECoG-based brain-computer interfaces (BCIs) is still hindered by the burden of frequent calibrations, which require extensive data collection, leading to potential user fatigue and signal degradation. Therefore, a rising interest in addressing inter-session variability and long-term signal drift emerges. Domain Adaptation (DA) strategies, adapted to online unsupervised scenarios, may offer a pathway to stabilize models' performances. Recent approaches typically rely on batch normalization either alone or paired with Euclidean or Riemannian alignments [1], requiring large storage of feature-space transformations. This work introduces a novel approach that incrementally aligns incoming data - target - to resemble what was previously seen by the model - source.

Material, Methods and Results: The developed method integrates a dual alignment strategy: (1) geometric, where the target's data structure is mapped to the source's one; and (2) distributional, to harmonize the target's statistical properties. Additionally, it leverages a compact latent space, reducing computational overhead and storage, opposing to literature's most recent studies attempting real-time data alignment. Pseudo-online results, obtained with three states classification data from the "STIMO-BSI" (NCT04632290) clinical trial [2], acquired using WIMAGINE technology [3], demonstrate significant improvements (F1-Score) in model performance across sessions over five months (Fig. 1).

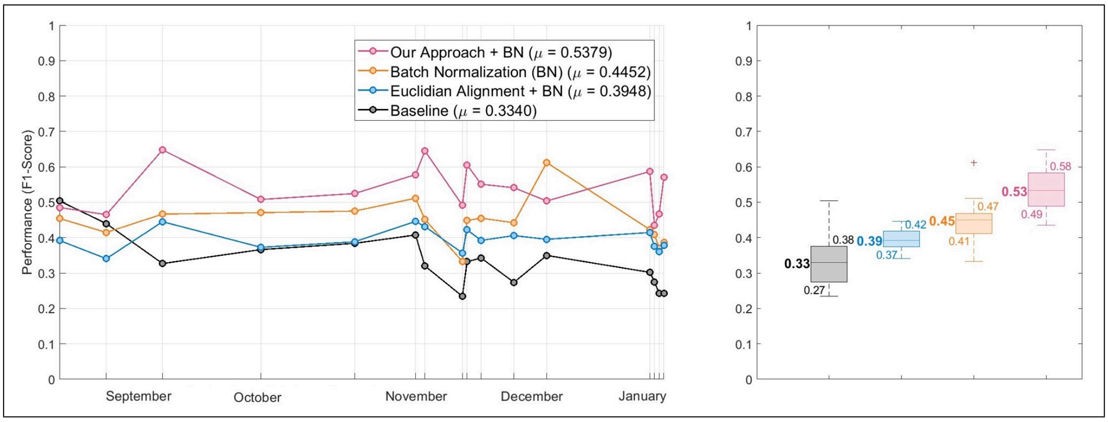

Figure 1: *Models' baseline performance compared with above-mentioned strategies and our approach, outperforming the others. The initial point represents the training day, while subsequent points correspond to the other existing sessions.*

Conclusion: This real-time incremental strategy surpasses recent methods in unsupervised online DA, advancing calibration-free ECoG-based BCIs and enabling more reliable use in home settings. Future work includes testing on additional datasets (e.g., more classes, upper limbs) and in online experiments.

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