Augmenting EEG with Generative Adversarial Networks Enhances Brain Decoding Across Classifiers and Sample Sizes

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***Abstract*—Introduction: The use of electroencephalography (EEG) in brain decoding has significant potential but is hindered by the need for large datasets. Advances in machine learning, particularly data augmentation techniques like Generative Adversarial Networks (GANs), offer a solution by generating synthetic EEG data to enhance classification performance. This study examines the effectiveness of GAN-augmented EEG data across different classifiers and sample sizes.**

Methods: We utilized a transformer-based GAN to generate synthetic EEG data and assessed its impact on classification performance using three classifiers: neural networks, support vector machines (SVMs), and logistic regressions. We conducted experiments across seven sample sizes (5 to 100 participants) to evaluate the performance enhancements.

Results: GAN-augmented EEG data improved classification performance for neural networks and SVMs but not for logistic regressions. The enhancement was more pronounced with smaller sample sizes, indicating that GANs are particularly beneficial for studies with limited data.

Discussion: Our findings suggest that GAN-augmented EEG can significantly enhance classification performance, particularly for neural networks and SVMs. The benefits diminish with larger sample sizes, likely due to the sufficient sample density already present in large datasets. This approach can facilitate research where collecting large amounts of data is challenging.

Conclusion: Augmenting EEG data with GANs enhances brain decoding capabilities, especially for smaller sample sizes. This technique is valuable for improving classification performance with neural networks and SVMs, providing a practical solution for research with limited data.

Keywords: EEG, GAN, Data Augmentation, Neural Networks, Support Vector Machine, Logistic Regression

Project Description: Replicate and Verify

Psychology and Machine Learning are largely empirical sciences and thus findings need to be independently replicated before they should be widely accepted. This is true for computational cognitive modeling as well. The final project involves picking a recent computational modeling paper and re-implementing and verifying the results reported by the authors. In doing this exercise, there might be opportunities to introduce new ideas about altering or changing features in their simulations that could be interesting. A couple of good sources for papers include the most recent Proceedings of the Cognitive Science Society (2023 and 2024) or the journal Computational Brain and Behavior.

Dataset Description

The dataset [1] consists of EEG brainwave data recorded from two individuals using a Muse EEG headband at the TP9, AF7, AF8, and TP10 placements. It encompasses three-minute sessions for each of three emotional states—positive, neutral, and negative—induced by specific film scenes, along with six minutes of resting state data per subject. This processed dataset, prepared with a novel statistical extraction method, serves as a foundational tool for research in EEG-based emotion recognition.

References

[1] Kaggle, ”EEG Brainwave Dataset: Feeling Emotions”. [Online]. Available: https://www.kaggle.com/datasets/birdy654/eeg-brainwave-dataset-feeling-emotions. [Accessed: Apr. 23, 2024].

[2] C. C. Williams, D. Weinhardt, M. Wirzberger, and S. Musslick, ”Augmenting EEG with Generative Adversarial Networks Enhances Brain Decoding Across Classifiers and Sample Sizes,” Proceedings of the 45th Annual Conference of the Cognitive Science Society, 2023. [Online]. Available: https://escholarship.org/uc/item/9gz8g908. [Accessed: Apr. 23, 2024].