NeuroLume: A Novel Framework Towards Multimodal Detection of Alzheimer's Disease Using EEG and Speech Biomarkers With Explainable Machine Learning

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Alzheimer's disease (AD) is a progressive neurodegenerative disease that continues to be difficult to diagnose in early stages. Despite studies demonstrating that when caught early, cognitive decline can be slowed by over 25%, timely diagnostic access remains limited as current clinical methods are costly and invasive. Furthermore, despite high accuracies from current models, clinical adoption remains slow as opaque models limit clinical interpretability. Thus, we present Neurolume: the first interpretable, low-cost, and non-invasive multimodal machine learning framework for early-stage Alzheimer's disease detection using EEG and speech biomarkers. EEG and speech data was first processed then analysed using interpretable and deep-learning models, including SVMs, CNNs, and a Transformer. Calibrated outputs from each modality were combined using late-stage fusion to estimate Alzheimer's disease probability. The EEG SVM provided stable feature-level interpretability while the CNN detected local spatiotemporal brain patterns producing AUC ˜ 0.91. The speech CNN failed to generalize, but the Transformer model captured linguistic and semantic cues of cognitive decline effectively, achieving high accuracy and AUC ˜ 0.95. Combining calibrated outputs from both modalities produced a robust multimodal classifier with AUC = 0.991, significantly surpassing all single-modality models and enabling reliable, non-invasive Alzheimer's detection. These results demonstrate that integrating interpretable neural and linguistic biomarkers enables accurate, scalable, and non-invasive early detection of Alzheimer's disease, with massive potential applications in improving accessibility to early screening.

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