Title: Scattering Feature Space Area for hypernasality detection in cleft palate speech across demographics in resource-limited settings

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Abastact: This study presents a Wavelet Scattering Transform (WST)-based framework for the objective assessment of hypernasality (HP) in cleft palate (CP) speech. A central contribution of the work is the Scattering Feature Space Area (SFSA), derived from a two-layer WST representation, which compactly captures the spectral–temporal dispersion associated with hypernasal resonance. SFSA is evaluated alongside additional WST-based dispersion measures to characterize how the geometry of the scattering space varies across different hypernasality levels. Statistical analyses including ANOVA, Kruskal–Wallis (K–W) tests, and effect-size evaluation demonstrate that SFSA and related features differ significantly across HP severity levels with minimal redundancy. The proposed method is assessed under a speaker-independent four-class classification protocol (Healthy, Mild, Moderate, Severe) using a train–test ratio of 85:15, inner 5-fold cross-validation, per-fold standardization, and grid-search optimization. Five shallow classifiers are compared with two convolutional neural network (CNN) baselines. Gradient Boosting (GB) achieves the highest macro-F1 scores across all demographics (male: 1.000; female: 0.909; child: 0.961), while Random Forest (RF) and Support Vector Machines (SVMs) also demonstrate stable performance. In contrast, the CNN baselines exhibit lower consistency in this data-limited scenario. Overall, the findings indicate that the proposed WST-based acoustic biomarkers are both interpretable for clinicians and effective for machine-learning models. SFSA, in particular, emerges as a geometric descriptor for objective hypernasality assessment in low-resource clinical environments.

Keywords: Hypernasality Cleft palate Acoustic biomarkers Wavelet Scattering Transform Scattering Feature Space Area Low-resource screening

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