Multiband Signal Compressibility for Real-Time ECG Quality Assessment in Body Surface Potential Mapping

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Aims: High-density Body Surface Potential Mapping (BSPM) requires efficient channel screening, yet current signal quality indices (SQIs) often rely on fiducial point detection or lack interpretability and diagnostic transparency. This study aimed to develop and validate a training-free, real-time SQI based on multiband signal compressibility to automate channel selection and eliminate the manual inspection bottleneck in clinical workflows.

Methods: A novel framework was implemented combining wavelet-domain multiresolution decomposition with compression-based information metrics. Signals were decomposed into three physiologically motivated bands: core ECG, high-frequency noise, and baseline wander. Each band was converted into a symbolic sequence via adaptive thresholding and quantified using a DEFLATE-based compression scheme to derive band-specific compressibility ratios, aggregated to obtain the global SQI (0–10). The method was validated using 1,050 synthetic signals with varying noise levels (0–30 dB SNR) and clinical 128-channel BSPM recordings from 30 patients with atrial fibrillation (Hospital Clínic de Barcelona, SAVE-COR and CURE-AF studies). Expert manual channel selection served as the reference standard.

Results: The SQI demonstrated a median execution time of 11.3 ms per channel, enabling full 128-electrode array screening in 1.45 seconds. Statistical analysis confirmed significant discrimination between clean, mild, and severe noise levels in synthetic data ($p < 0.001$). Clinical validation yielded 90% agreement with expert manual selection, with a sensitivity of 0.97, a positive predictive value of 0.88, and an F1-score of 0.92. The sub-band approach allowed for specific identification of baseline drift and muscle artifacts, providing diagnostic transparency.

Conclusion: The proposed multiband compressibility framework provides an objective, interpretable, and computationally efficient measure of signal quality. By matching expert performance in real-time, this approach eliminates the need for subjective manual inspection, significantly improving the scalability and reliability of high-density non-invasive cardiac mapping systems.