OCA-SENTINEL: Multimodal Age Group Prediction System

Our approach predicts age groups (20s-70s, 6 classes) from dual-modality arterial pressure waveforms using a transformer-based bootstrap ensemble architecture. The system employs a comprehensive data processing pipeline beginning with Butterworth 4th-order low-pass filtering (fs=500Hz, cutoff=25Hz) applied to valid signal segments, followed by StandardScaler normalization fitted exclusively on non-missing values to preserve data quality. Missing values are handled natively through boolean masks without imputation. We utilize bootstrap aggregating (bagging) with 10 independent models, where each model is trained on a different bootstrap sample (sampling with replacement from 2700 subjects), creating diverse training sets that reduce variance and improve generalization.

The core architecture features dual-stream transformer encoders, one per modality (Aortic and Brachial pressure). Each encoder projects 1D time series into 128-dimensional embeddings enhanced with sinusoidal positional encoding, then processes them through 4 transformer layers with 8 attention heads and 512-dimensional feedforward networks. Adaptive attention masking prevents gradient flow from missing time points, enabling robust representation learning despite incomplete sensor data. The encoded representations are concatenated (256-dim) and passed through a classification head with dropout (0.5) to predict one of six age groups. Training employs AdamW optimizer (lr=0.0001, weight_decay=0.01) with CrossEntropyLoss over 120 epochs using ReduceLROnPlateau scheduling.

The ensemble achieves 84.4% ± 2.4% mean validation accuracy across all models (range: 80.9%-89.2%). Final predictions combine probability distributions from all 10 models via averaging, then apply argmax for classification. This approach demonstrates robust performance with balanced predictions across all age groups (14-19% per class) on 875 test samples, completing inference in approximately 15 minutes on CPU.