ABSTRACT

Cardiovascular disease (CVD) is the leading cause of death worldwide, particularly in low- and middle-income countries. Its prevalence continues to rise, with 887,531 recorded cardiac cases in Indonesia in 2023, an increase of 0.85 % from the previous year. Arrhythmias, such as atrial fibrillation (AF), contribute significantly, accounting for 46.3 million global cases and projected to increase further by 2050; AF elevates stroke risk by up to five-fold.

In ECG-signal classification, the bagging method enables heartbeat grouping in accordance with AAMI standards. Bagging trains multiple *base learner* in parallel on different *bootstrap*-sampled subsets of data; in this study, *Traditional Bagging*, *Bayesian Bagging*, *Feature Bagging*, and *Random Subspace* were implemented to optimise classifier performance.

This research investigates *ensemble machine learning* with a *bootstrap*-aggregation (bagging) framework to improve arrhythmia-classification *accuracy* on multi-lead electrocardiogram signals. Significant *features* were identified and optimised to distinguish arrhythmia types, and the bagging *ensemble*s were benchmarked against a single model and other *ensemble* approaches. All bagging architectures outperformed the single decision-tree baseline, with *Bayesian Bagging* achieving the highest performance (*accuracy* = 93.40 %, F1-score = 93.50 %, ROC AUC = 99.30 %) and an inference time of only 0.10 s. These gains are attributed to Dirichlet weighting, which preserves each sample's contribution across all models and retains non-linear patterns in complex *features*. Compared with boosting and stacking, the bagging framework provides an optimal balance of *accuracy*, metric stability, and computational efficiency, making it a reliable approach for ECG-based arrhythmia-detection systems.

Keywords: Arrhythmia, Electrocardiogram, *Bootstrap aggregating*, *Bayesian Bagging*, *Ensemble Machine learning*, MIT-BIH Arrhythmia.