Hyperparameter Optimization of Multivariate Adaptive Regression Splines for Clinical Electrocardiographic Imaging

Canberk Almus, Jana Svehlikova, Yesim Serinagaoglu Dogrusoz

Middle East Technical University
Ankara, Türkiye

Background: *Electrocardiographic Imaging (ECGI) reconstructs cardiac electrical activity non-invasively from body surface potentials, but it is an ill-posed inverse problem. Multivariate Adaptive Regression Splines (MARS) provide a data-driven alternative to traditional regularization, yet become computationally expensive on high-resolution clinical data. This study proposes a patient-specific adaptive strategy that dynamically scales MARS model complexity to improve efficiency while preserving localization accuracy.*

Methods: *Clinical data from 10 patients with premature ventricular contractions (PVCs) were analyzed. Training data were simulated using a cellular automaton and Boundary Element Method on inhomogeneous geometries. Parametric sweeps assessed key MARS parameters (threshold-ϵ and term limit-L_{max}). An adaptive L_{max} formulation was developed using a patient-specific saturation model based on spatiotemporal volume (V) to balance data availability and model complexity.*

Results: *High-complexity baseline model ($L_{max} = 128$, $\epsilon = 0.001$) yielded accurate results (LE: 17.2 mm) but required impractical runtimes (43.4 hours). The proposed adaptive strategy (L_{max}) outperformed static constraints, reducing the mean localization error (LE) in the calibration set from 18.85 mm to 15.99 mm. In a representative clinical validation case, the adaptive model achieved an LE of 14.4 mm while reducing runtime from 49.8 hours to 9.5 hours.*

Conclusions: *Directly constraining L_{max} provides more reliable control over model complexity than threshold-based stopping, which can prematurely halt fitting. Scaling L_{max} with patient-specific data volume reduces overfitting while preserving physiological signals, improving the feasibility of MARS-based ECGI for pre-procedural planning. Further reductions in runtime are still needed.*