Domain-Specific Regularization Strategies for ECG Waveform Boundaries in 1D Region Proposal Networks

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Standard Region Proposal Networks lack domain-specific constraints necessary for robust ECG waveform detection. We propose four regularization strategies – Variance, RMSE, CVaR, and LSE – that embed morphological priors directly into the loss function of a two-stage 1D detector. Evaluating 74 training runs across synthetic and LUDB datasets, we show that regularization effectiveness is fundamentally dataset-dependent. While clinical recordings achieved up to 49.6% improvement in QRS localization, identical constraints degraded synthetic performance by 16.0%. This suggests regularization acts primarily as an implicit denoising mechanism for clinical variability rather than a universal geometric enforcer. Offset boundaries showed 2-3× larger gains than onsets, with tail-focused losses (LSE, CVaR) proving most effective. These findings demonstrate that clinically-aware loss design must prioritize data-specific noise characteristics over rigid morphological stability.

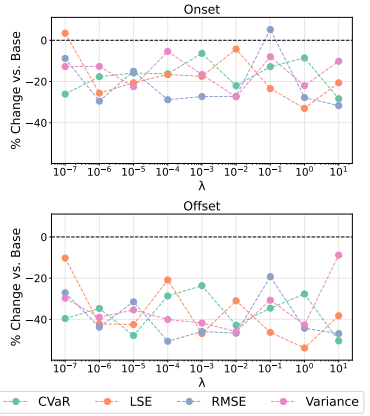

Figure 1: Synthetic dataset: Relative RMSE change.

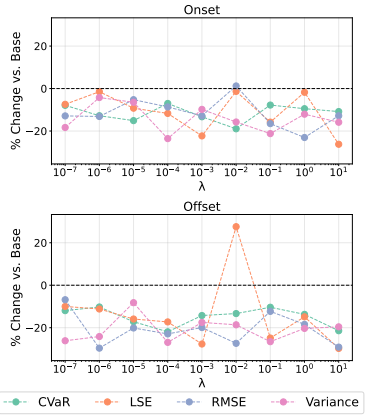

Figure 2: LUDB dataset: Relative RMSE change.