Multi-tapered Spectral Point Process Models for Multimodal Sleep Arousal Detection

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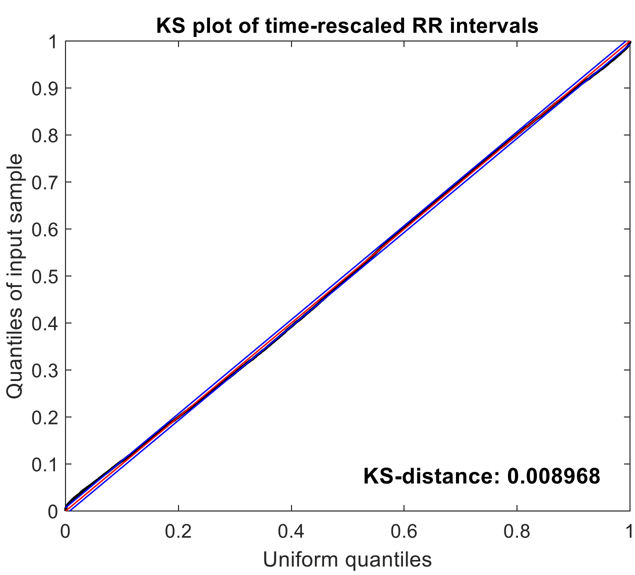
The goal of this CinC Challenge is to call non-apneic, non-hypopnic arousal events during sleep using a multimodal approach incorporating EEG, EOG, EMG, ECG, and oxygen saturation levels (SaO2) data. Our proof of principle study sampled 60-second epochs of data across 30 subjects randomly chosen from the full training set. We performed logistic regression based on a set of 101 multimodal features that included a spectral characterization of the alpha, theta, and delta power bands in EEG, delta power in EOG, total power in EMG, and instantaneous heart rate variability measures computed from ECG. Of note, all power spectra were calculated using the multi-taper spectrogram method, which reduces the variance and therefore the uncertainty in the power spectral density estimates. In addition, we used a point process based heart rate variability algorithm that models the RR-interval as a history-dependent inverse Gaussian process and has been validated both physiologically and statistically. Goodness-of-fit tests showed that this model was appropriate for all individual subjects' data in our training set. As of now, we have achieved a training set AUROC of 0.591 and AUPRC of 0.119, both of which represent nontrivial improvements over chance (the proportion of arousals across our training set was 0.089). While this exploratory attempt is a first step, we aim to improve our score in future work by using the full training and testing datasets, rebalancing the classes (arousal and non-arousal) by resampling, designing better ways to deal with missing data, incorporating more sophisticated classification methods such as neural networks or LSTMs, and more specifically pruning the features for those that are both relevant and physiologically informed. With these approaches along with the physiological and statistical rigor of our features, we believe we can achieve high sensitivity, specificity, and positive-predictive value.



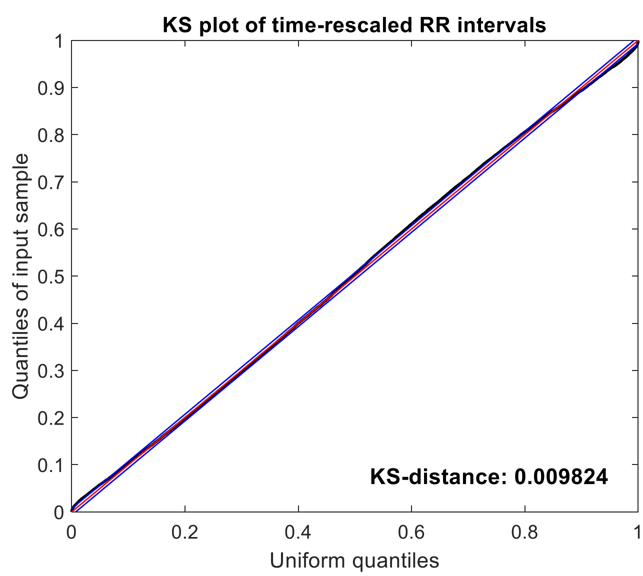


Figure 1: These are Kolmogorov-Smirnov (KS) plots for two subjects from the training set showing the fit of an inverse Gaussian point process model to the RR-intervals in their respective ECG data using the Time Rescaling Theorem to convert the point process model to a Poisson process with rate 1. The KS plot shows the theoretical cumulative distribution function (CDF) in red with 95% confidence bounds in blue against the empirical CDF in black. The empirical CDF remains largely within the confidence bounds. The computed KS distance quantifies this fit; the smaller this distance, the better the fit.