Analyzing Fetal Heart Rate Patterns via Latent Representations with Variational Recurrent Neural Networks (VRNNs)

Mahdi Shamsi[1], Aditi Lahiri, Yvonne Wu, Lawrence Gerstley, Michael Kuzniewicz, Cornet Marie-Coralie, Emily Hamilton, Philip Warrick, Robert Kearney

[1]McGill University,
Montreal, Canada

Background: Latent representations in machine learning, play an important role in extracting and interpreting complex, high-dimensional data. In the context of biomedical signals, these latent representations are invaluable for downstream tasks. They serve as a compact, yet comprehensive encapsulation of the original data, capturing essential features and underlying patterns that may not be immediately apparent from the raw signal. Building on the foundation of Variational Autoencoders (VAEs), Variational Recurrent Neural Networks (VRNNs) introduce a dynamic advancement, particularly suited for time-series data such as fetal heart rate (FHR) signals. VRNNs extend the capabilities of VAEs by incorporating the temporal dependencies inherent in biomedical signals, providing a more comprehensive encoding of the evolving patterns in the FHR signal.

Aim: This study provides an analysis of the latent representation of FHR signal using scattering transform and VRNN model with respect to FHR signal features and events such as acceleration, deceleration and baseline.

Method: A data set from Kaiser Permanente Northern California hospitals was assembled from 14,372 ten-minute epochs of FHR records from 1,012 singleton vaginal births with healthy outcome.

First, the scattering transform was applied with a maximum wavelet scale of 11 to transform the raw FHR signals. The first 11 scattering coefficients were then used as input for the VRNN model, which incorporates a four-layer Gated Recurrent Unit (GRU) for its recurrent block. The two critical hyperparameters of the model which control the model capacity are the size of hidden states of the recurrent block and the dimension of the latent variable which were set to 66 and 9, respectively.

Results: Figure 1 presents a correlation graph that illustrates the relationship between the features of dimensions 4 and 2 of the latent variable and FHR event including deceleration, acceleration, and baseline. Note that threshold of ± 0.5 was considered to draw an edge between the two correlated variable. The comprehensive analysis of all dimensions of the latent variables and FHR event features reveals a significant correlation between them.

Conclusion: The analysis results demonstrate that the features of the latent representation from the VRNN model are significantly correlated with the FHR event features, confirming that the latent representation effectively captures critical information from the FHR signal.

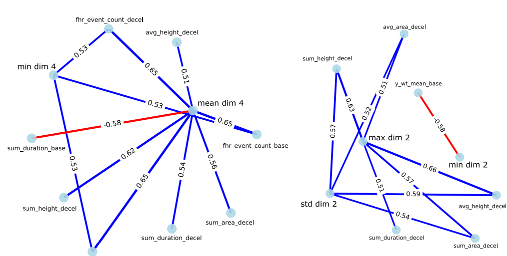

Figure 1: Correlation graph of latent variable features with FHR event features.