Modeling-based Radial Pressure Waveform Reconstruction using Photoplethysmography Signals

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Aims: While photoplethysmography (PPG) signals are increasingly used in healthcare, understanding the physiology encoded by PPG remains a challenge. First, we proposed an explicit model linking the PPG dynamics to the variations of the radial pressure waveform (RPW) and then used this model to reconstruct RPW from PPG measurements given pulse pressure extrema.

Methods: We derived the model leveraging existing literature and conducting supervised symbolic regression on a partner hospital anaesthesia database. The model validation was conducted on 224 continuous subsequences of 20 seconds. The first 10 seconds were used to make the model patient-specific through an unscented Kalman filter. The remaining 10 seconds served to assess the prediction of either the PPG or the RPW signals coming from the calibrated model.

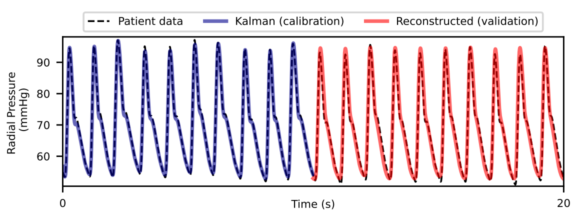

Fig: RPW reconstruction (hypotensive case)

Results: Identifying the symbolic model yielded several formulations of varying complexities; we selected the most parsimonious form. The model resulted in a linear Ordinary Differential Equation (ODE), which can be interpreted physically, with 3 parameters. The ODE showed consistency with previously existing models and enhanced their dynamics. As the PPG's signal intensity cannot be used quantitatively, the subsequence's maximal systolic and minimal diastolic pressures are needed to rescale the RPW. The parameters were identifiable and showed patient-specific features within gaussian distributions. Once the parameter calibration converged, the parameters did not drift. The reconstructed PPG and RPW signals showed a good fit with the data, with a 12% $\mathcal{L}^2$-norm error.

Conclusion: The proposed model enables the estimation of the RPW from non-invasive measurements, using PPG and a blood pressure cuff. The small overall variability of the model parameters highlights its potential. In perspective, we are currently extending the validation to the MIMICS database.