Uncertainty in PPG-Based Cuffless Blood Pressure Trend Monitoring: A Personalized Approach

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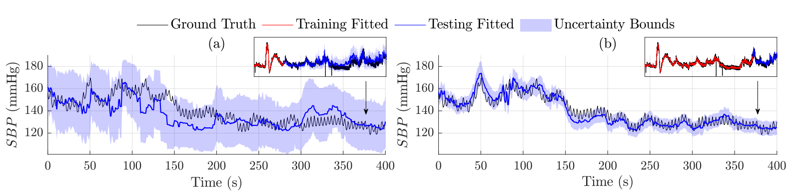
Introduction. Cuffless blood pressure (BP) monitoring using photoplethysmography (PPG) is increasingly being integrated into wearables to track conditions such as hypertension. However, rather high uncertainty of continuous BP monitoring solutions, mainly related with inter-personal variations, limits effective applications. This study aims to propose a personalized PPG analysis-based method for the estimation of cuffless BP and providing uncertainty bounds.

Methods. The PulseDB Vital database consisting of 2938 non-cardiac surgery patients was used, containing finger PPG signals and reference invasive BP measurements. A Gaussian process regression (GPR) model was implemented to predict systolic and diastolic BP from 28 PPG pulse wave features. The parameters of the model were determined via a person-specific method by training the model for each subject individually. Additionally, the moving-median filter was used for feature post-processing to mitigate outliers. The uncertainty of individual predictions was quantified using prediction intervals estimated by the GPR model. The optimal segment with the largest BP change was selected for training, and performance was assessed when using different training-testing data splits of 1:4, 1:2, 1:1, 2:1, and 4:1.

Results. The highest proportion of subjects with a mean absolute error less than 5 mmHg and lowest prediction uncertainty was achieved with the sub-optimal training-testing ratio of 4:1 (19.54% $>$ 14.64% $>$ 10.72% $>$ 8.61% $>$ 7.08% and 52.42% $>$ 47.35% $>$ 41.12% $>$ 35.94% $>$ 28.25% for systolic and diastolic BP, respectively). For diastolic BP, the performance errors and uncertainty metrics were significantly lower compared to systolic BP ($p < 0.001$, matched-pairs $r_c \geq 0.90$).

Conclusion. The study demonstrated that extending the training segment per subject record leads to reduced errors and, consequently, substantially decreased quantified uncertainty in BP prediction. This shows that the proposed method has the potential to accurately estimate cuffless BP by individually optimizing the training duration for the model.



The example of person-specific estimated trends in systolic BP with uncertainty bounds using training-testing ratios of: (a) 1:4, (b) 4:1.