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Fabienne Sahl, Sebastian Zaunseder

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Non-Invasive Physics-Informed Cardiac Output Estimation

Fabienne Sahl, University of Augsburg, Chair for Diagnostic Sensing, Augsburg, fabienne.sahl@uni-a.de

Sebastian Zaunseder, University of Augsburg, Chair for Diagnostic Sensing, Augsburg, sebastian.zaunseder@uni-a.de

Introduction

Cardiac output (CO) is a key parameter of the cardiac function. Reduced CO can lead to insufficient organ perfusion. However, accurate CO measurement typically requires invasive methods, limiting CO's availability. Recent works try to estimate CO from easily available biosignals. In this study, we investigate an approach to estimate CO using a physics-informed multilayer perceptron based solely on photoplethysmography (PPG) features.

Methods

Features from different measurement sites (finger, ear, and facial remote PPG) are evaluated individually and in combination. To incorporate physiological knowledge, the IHAR feature, defined as the normalized harmonic area divided by the inflection point area ratio, (strong correlation between IHAR and CO were shown previously) is embedded into the training process via a physics-based loss function. The data used originates from an own study (43 participants included) comprising multiple stimuli inducing changes in CO. CO was derived using the volume clamp technique, thus representing an estimate. Model performance is evaluated using mean absolute error (MAE) and Pearson correlation coefficient.

Results

Incorporating the physics-based loss improves CO estimation compared to models without physiological constraints across all PPG configurations by up to 28 %. The best performance of leave one subject out cross validation is achieved using facial remote PPG, yielding a MAE of 1.07 l/min and a Pearson correlation coefficient of 0.37, matching the literature for CO estimations using solely PPG.

Conclusion

This work demonstrates the potential of integrating physiological knowledge into neural network training for non-invasive CO estimation. However, the limitations of the underlying dataset highlight the need for further validation using independent databases with clinically measured CO. Expanding the range and quality of reference data, alongside a deeper integration of physiological mechanisms, will be crucial for improving model accuracy and clinical applicability.