Machine Learning-Based Respiration Rate and Blood Oxygen Saturation Estimation Using Photoplethysmogram Signals

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SCAN ME

INTRODUCTION

The COVID-19 pandemic has had a significant impact on the world, particularly on healthcare systems. Remote vital sign measurement devices can reduce hospital visits for COVID-19 patients and help healthcare professionals monitor their vital signs from home. Recent advancements in respiration rate estimation techniques using PPG waveforms have shown promise in accurately monitoring patients.

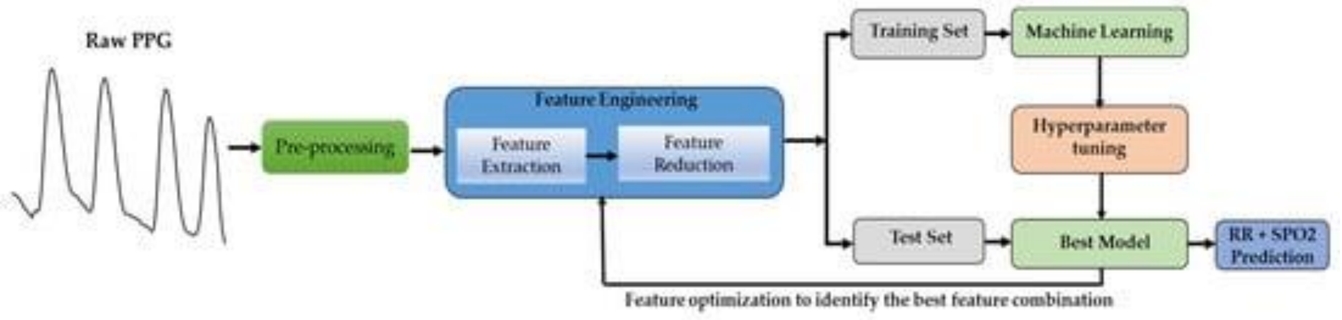

Figure 1. Overview of the machine learning system development.

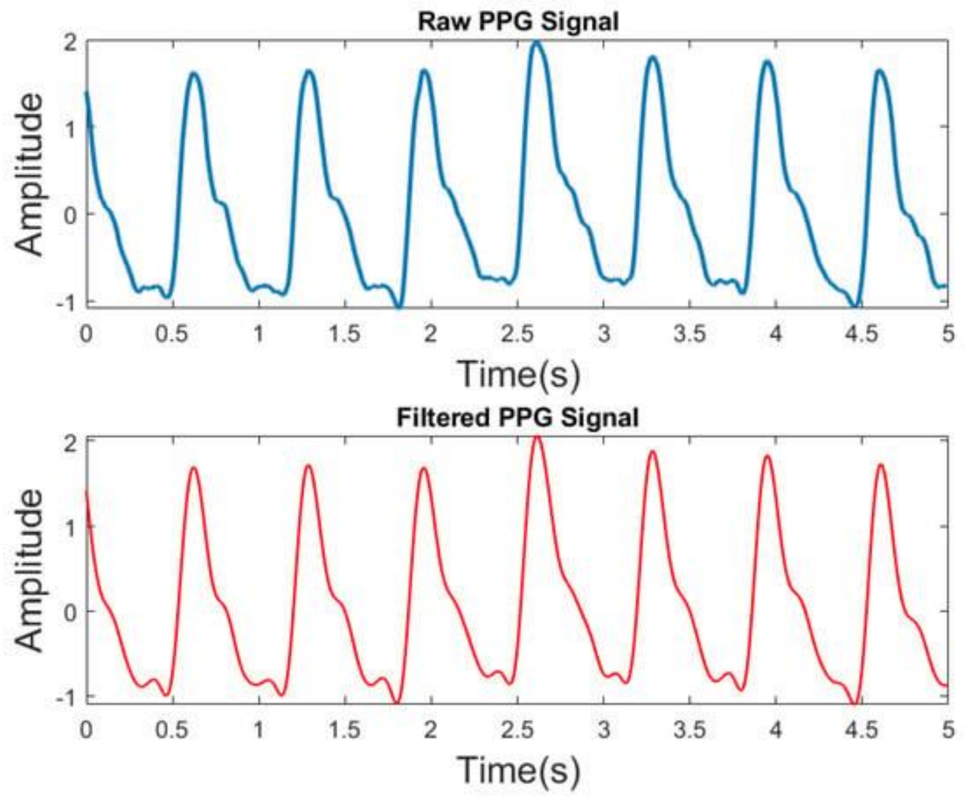

Figure 2. Raw PPG and filtered PPG signals.

METHODOLOGY

This study aimed to estimate respiratory rate (RR) and peripheral oxygen saturation (SpO2) using machine learning models trained on photoplethysmogram (PPG) signals from the publicly available BIDMC dataset. The dataset included 53 recordings of ECG, PPG, and impedance pneumography signals from adult ICU patients. PPG signals were filtered and motion artifacts were removed using Variational Mode Decomposition (VMD). Features were extracted and feature selection methods were employed to reduce overfitting and computation time. Machine learning models were trained, validated, and tested using the chosen features to estimate RR and SpO2.

Time, frequency, and statistical features are extracted, and 107 features are obtained. Nine feature selection algorithms are used, and the best algorithm is chosen based on empirical results. Five machine learning models, with 19 variants, are trained, validated, and tested using five-fold cross-validation. The models include Gaussian Process Regression, Ensemble Trees, Support Vector Regression, Decision Trees, and Linear Regression.

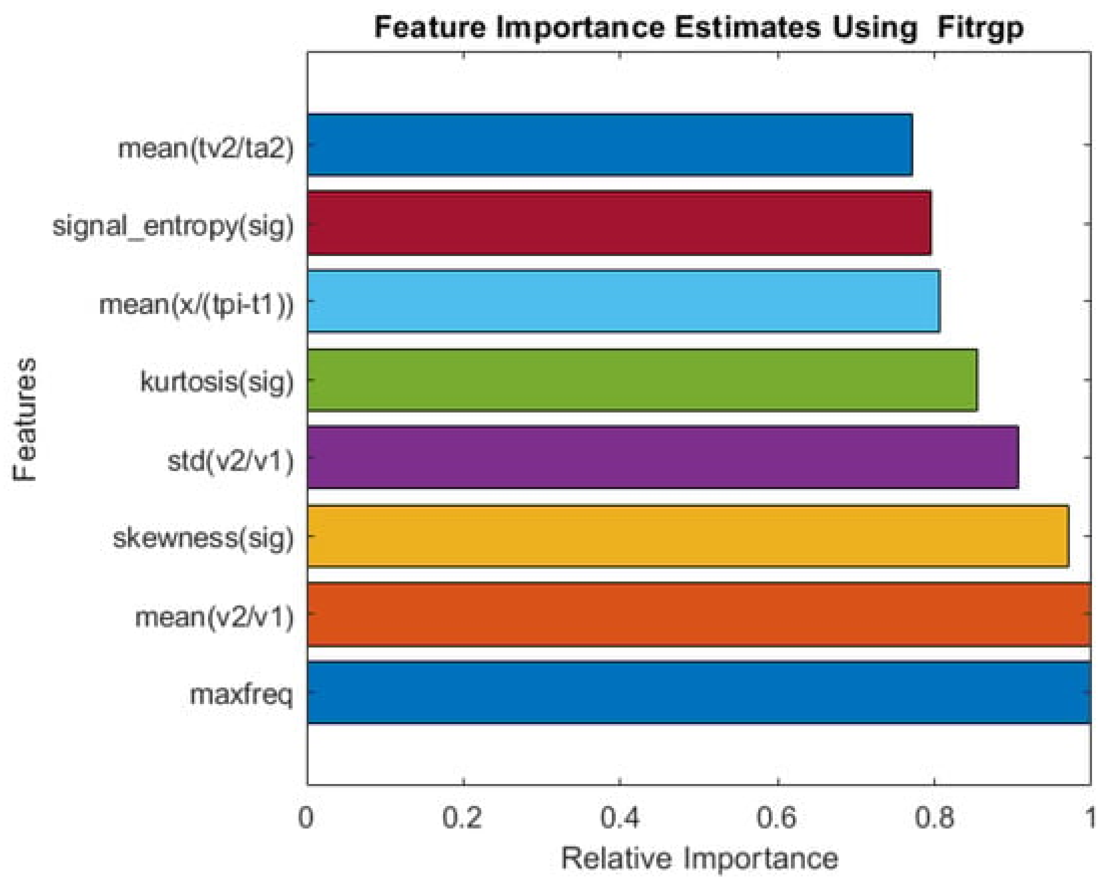

Figure 3. Relative importance of the top eight features selected by the Fitrgp algorithm for RR estimation.

CONCLUSION

- A new method for estimating respiration rate (RR) and oxygen saturation (SpO2) from photoplethysmogram (PPG) signals is proposed. Machine learning models map features extracted from PPG signals to RR and SpO2 values.
- Pre-processing and feature extraction steps were performed, reducing 107 features to improve computational efficiency.
- Separate models were trained for RR and SpO2 using 38 models, with Gaussian process regression performing best. The models outperformed previous literature and can be useful for developing wearable real-time RR and SpO2 estimation devices.

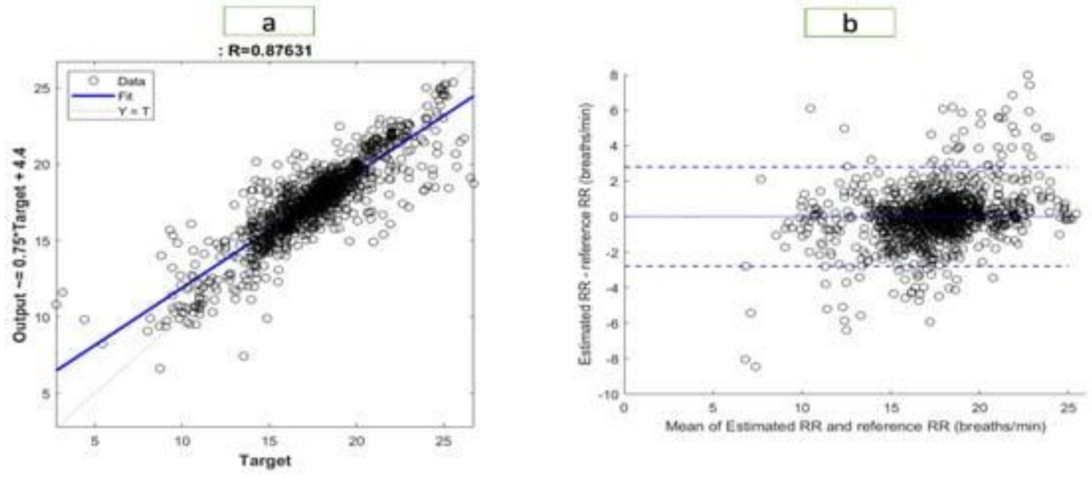

Figure 4. Visualization of the results for RR with (**a**) a regression plot (**b**) a Bland–Altman plot.

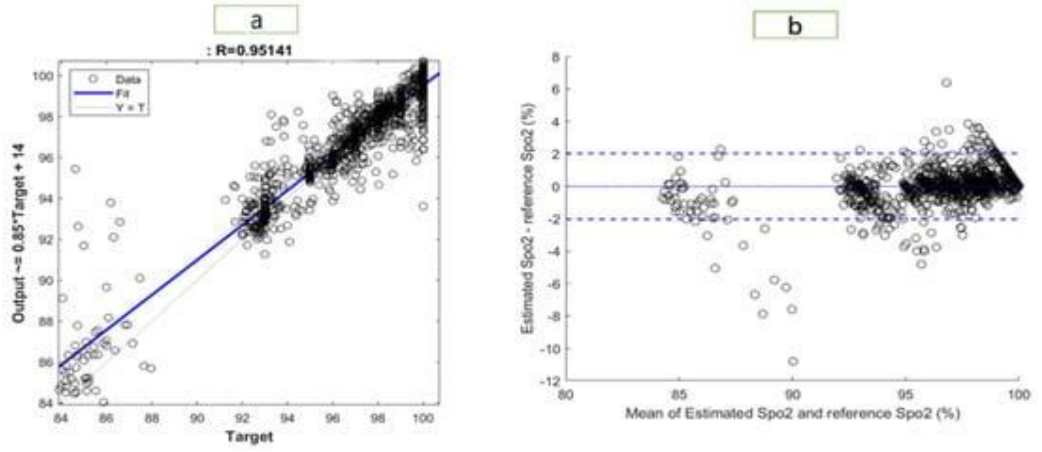

Figure 5. Visualization of the results for SpO2 with (**a**) a regression plot (**b**) a Bland–Altman plot.

DISCUSSION

The results of this study demonstrate that the proposed machine learning model accurately estimates respiration rate (RR) and oxygen saturation (SpO2) from photoplethysmogram (PPG) signals. By extracting 107 features and using feature selection algorithms to reduce computational complexity, the study produced 38 separate models for RR and SpO2. Gaussian process regression proved to be the best model, achieving an RMSE of 1.41 and an MAE of 0.89 for RR, and an RMSE of 0.98 and an MAE of 0.57 for SpO2. These models outperformed those reported in the literature.

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