Reconstruction of Corrupted Photoplethysmography Signals to Facilitate Continuous Monitoring

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Aims: Photoplethysmography (PPG) is the leading technology behind wearables. Despite its high popularity, PPG signals are susceptible to motion artifacts (MAs), significantly hindering continuous health monitoring. While MAs detection is vastly investigated, how information could be retrieved afterwards is yet to be defined. This study presents an innovatory algorithm able to reconstruct all-source corrupted PPGs for further use in cardiac analysis.

Methods: Artifact detection is initially performed by a three-level spectral and amplitude-based control. Corrupted signal is then reconstructed based on morphology, spectral and heart-rate (HR) variability (HRV) information of the adjacent clean segments. Thirty-six 8-minute originally clean PPGs with a sampling frequency of 125 Hz were used. Recordings were resampled to 250 Hz. Artificial noise was added, with a sequential duration of 2–120 s. HR and HRV features were compared between original and reconstructed PPGs for all noise lengths via Pearson correlation (ρ), Bland-Altman (BA), normalized root mean square error (nRMSE) and mean absolute percentage error (MAPE) analysis.

Results: For HR, $\rho > 0.9$ for all noise lengths. Time-domain HRV: $\rho > 0.91$ (up to noise of 45 s: $\rho > 0.98$). Frequency-domain HRV: $\rho > 0.75$ (up to 45 s: $\rho > 0.88$). Poincaré indices: $\rho > 0.85$ (up to 45 s: $\rho > 0.92$). Maximum nRMSE was 0.58% and MAPE was 1.72% ($nRMSE_{45s} \leq 0.32\%$, $MAPE_{45s} \leq 1.22\%$). At least 86% of recordings were within confidence interval (95% limits of agreement) for all features in BA, with most results being between $89\% - 97\%$, regardless of noise duration.

Conclusions: The proposed algorithm allows the reconstruction of corrupted PPG signals, regardless of the source of noise. The continuous noise duration up to which it shows optimal results is 30–45 s. Nevertheless, it can be used for longer segments, providing satisfactory results. Fundamental cardiac features can be reliably calculated from the reconstructed signals, suggesting the implementation of the presented algorithm in wearable devices.