Vital Sign Extraction from Abdominal Audio Signals

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Abdominal sounds (ABS) have been traditionally used for assessing gastrointestinal (GI) disorders [1]. However, such assessment requires a trained medical professional to perform multiple abdominal auscultation sessions, which is resource-intense and does not allow monitoring of a patients' GI wellbeing continuously. This has generated a technological interest in developing wearables for continuous capture of ABS [2]. This work seeks to evaluate the feasibility of extracting vital signs such as heart rate (HR) and heart rate variability (HRV) from ABS monitoring devices. The collection of audio at the abdomen directly from these devices would enable gathering vital signs alongside GI data without the need for additional wearable devices, providing further cost benefits and improving general usability. We utilised a dataset [3] containing 104 hours of ABS audio, collected from the abdomen using an e-stethoscope, and electrocardiogram as ground truth. Our evaluation shows for the first time that we can successfully extract HR from audio collected from a wearable on the abdomen. As heart sounds collected from the abdomen suffer from significant noise from GI and respiratory tracts, we leverage wavelet denoising for improved heart beat detection. The mean absolute error of the algorithm for average HR is 3.4 BPM with mean directional error of -1.2 BPM over the whole dataset. Results are also demonstrated for tracking of the ground truth and longitudinal tracking of an individual participant over a week. The algorithm is also compared across participants who have different resting heart rates which is shown to affect performance. A Bland-Altman analysis shows a negative gradient for both average and instant HR, this indicates that the algorithm is biased to more central values of heart rate, this is verified in analysis of the tracking of audio HR to the ground truth. A comparison to photoplethysmography-based wearable HR sensors shows that our approach exhibits comparable accuracy to consumer wrist-worn wearables for average and instantaneous heart rate. Further to this, we show feasibility for extracting HRV and potential for HRV-derived respiratory rate from Respiratory Sinus Arrhythmia (RSA), a coupling between breathing and heart rate. This study demonstrates the opportunity for monitoring both ABS and vital signs from one device worn at the abdomen, which can be integrated into unexplored form factors such as belts and elastic bands. This opens up new avenues for being fully integrated and widely accepted into existing clothing designs. While this study proves the feasibility of vital sign extraction, further work would look to use more sophisticated segmentation techniques for heart sounds to increase localisation of heart peaks and improve method's robustness.

References

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