Source Separation of the Second Heart Sound via Alternating Optimization

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Aims: Cardiovascular diseases associated with pulmonary artery hypertension are a significant burden for healthcare systems, due to difficult early recognition and high cost of the corresponding treatments. Cardiac auscultation is a potential cost-effective alternative to cardiac catheterization and Doppler echocardiography to estimate the pulmonary artery pressure (PAP), given its low cost, non-invasive nature, and simplicity. On the other hand, accurate estimation of the PAP from auscultation requires handling separately the two main constituents of the second heart sound (S2), i.e., the aortic component (A2) and the pulmonary component (P2). This separation problem, however, is highly non-trivial, given the large time-frequency overlap and similar morphology of the two components.

In contrast with previous approaches that appeared in the literature, the proposed method allows the A2 and P2 components of S2 sounds to be recovered accurately without leveraging predetermined waveform models and without requiring any annotated training data.

Methods: The proposed method is based on the observation that A2 and P2 components in different heartbeats change their relative delays (due to the variations in the thoracic pressure induced at different respiration phases) while approximately maintaining the same waveform. This information is leveraged by defining the separation problem as a least-squares optimization problem which is solved using an alternating optimization method over the shapes and positions of the A2 and P2 components.

Results: The proposed approach was tested over synthetic data and compared with recent approaches: (Tang et al. (2017)) and (Renna et al. (2019)).

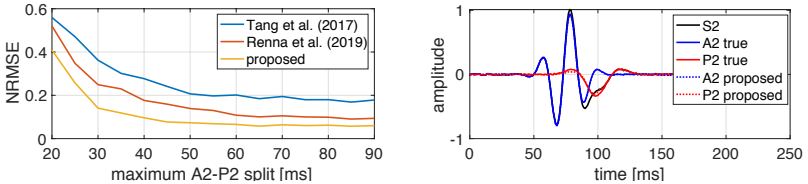

Fig. 1: Normalized root mean-squared error (NRMSE) and reconstruction example.

Conclusions: Although testing with real-word data is required, the proposed unsupervised method recovered A2 and P2 components more accurately than current unsupervised and supervised state-of-the-art approaches.