Abstract

The human body generates a diverse range of biosignals that characterize the physiological state of the vital organs of the body. Heart sounds, the acoustic signal generated by the mechanical activity of the heart and blood flow, are one of the oldest biosignals used for diagnostic purposes. However, our limitations as a human listener have constrained its use for the diagnosis of cardiac diseases. Nevertheless, the advent of machine learning and signal processing techniques for biosignals has given a fillip to the detection of myriad cardiovascular diseases (CVD) using the electronic record of heart sounds, termed as phonocardiogram (PCG). Among various CVD, coronary artery disease (CAD), a chronic cardiac disorder is gaining interest for PCG based study as it can serve as noninvasive, point-of-care diagnostic tool in comparison to the existing methods. The focus of this dissertation is to investigate a hierarchy of features for CAD detection using multichannel PCG signals. The experiments for the proposed methods are performed on PCG signal acquired from four auscultation sites on the left anterior chest. The proposed frameworks are compared with two baselines, referred as baseline-1 and baseline-2. Baseline-1 is based on bag-of-features approach and baseline-2 on subband moments of power spectrum density.

Heart sounds propagate to different auscultation sites with delay, accompanied with change in waveform. However, the abnormalities get manifested in them as a whole. We compare cross power spectrum density (CPSD) of PCG from two auscultation sites as a toolbox for spectrum analysis. However, instead of using the magnitude of CPSD, we use imaginary part of CPSD. Imaginary part renders advantage in terms of robustness against ambient/environmental noise. With subband based features, proposed method performed comparable to baseline-2 and was better than baseline-1.

Spectrum analysis fails to capture the transient abnormalities occurring at different phases in the cardiac cycle. In the second hierarchy, we study one of the reassignment time-frequency representations, namely Synchrosqueezing transform

(SST) using time varying entropy in its subbands. Later, a score-level fusion of possible channel combinations is performed to amplify the performance. Results show considerable relative improvement from both the baselines.

Finally, we step towards a higher-order of hierarchy for features, namely representation learning. Handcrafted features require domain knowledge as well as the ability to represent the discriminative factors with corresponding metrics. However, there may be some latent factors which are not available as observable quantities. Pre-trained Convolutional Neural Network are used to obtain such latent features from SST of PCG. Later, a multiple kernel approach is proposed for fusion of entropy features extracted previously from SST and learned representations from SST. This proposed framework surpasses all the previous contributions and baselines in accuracy by noteworthy improvement.

Thus, overall this dissertation shows the potential of developing a non-invasive, inexpensive, point-of-care diagnostic CAD detection system using PCG. Such a system is expected to improve the healthcare accessibility in general and reach out to the marginalized in particular.

Keywords: Atherosclerosis, Convolutional neural network, Coronary artery disease, Imaginary part of cross power spectral density, Multichannel, Multiple kernel learning, Phonocardiogram, Synchrosqueezing transform, Transfer learning.