Abstract

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Cardiovascular diseases (CVDs) are the leading cause of high mortality rates in India due to unhealthy lifestyles and lack of daily exercise. The continuous recording and monitoring of 12-lead ECG data are highly required for the diagnosis of CVDs. A huge volume of data is produced during the continuous recording of 12-lead ECG data from the subject for arrhythmia monitoring in the intensive care unit (ICU). Therefore, efficient methods for automated analysis of the huge volume of 12-lead ECG data are required for the accurate detection of CVDs. This thesis work documents the development of tensor domain machine learning approaches for automated detection of different CVDs using longer duration 12-ECG recordings.

There are five major contributions. The first contribution is the multi-lead fusion (MLF) algorithm for accurately detecting the QRS complex. The QRS complex is dominant in the cardiac cycle or beat. Hence detection of the QRS complex is the first step in automated ECG signal analysis algorithms. The second contribution proposes a third-order tensor-based cardiac disease detection method. The 12-lead ECG beats are decomposed into modes by multivariate projection-based fixed boundary empirical wavelet transform (MPFBEWT). Th 3D tensor formed contains the information of lead, modes and samples. This 3D tensor is fed to a deep Convolutional neural network (CNN) to classify various classes of cardiac diseases. This 3D tensor contains the information of a beat only. For the patient-specific model, where complete patient information can be processed, a higher-order tensor is required. The third contribution proposes a patient-specific fourth-order tensor-based approach for the detection of Myocardial Infarction (MI). A fast and adaptive multivariate empirical mode decomposition (FA-MVEMD) is used to decompose the 12-lead ECG data into the modes. A 4D tensor containing the information of lead, beat, mode and sample has been formulated. The tensor domain feature extracted after multi-linear singular value decomposition (MLSVD) is further classified by the KNN, SVM and stacked autoencoder-based deep neural network (SAE-DNN). The proposed 4D tensor-based approach shows improved performance over the existing method for MI detec-

tion. The fourth contribution of this thesis proposes a fifth-order tensor base bundle branch block detection method using multivariate fast-iterative filtering (MVFIF) decomposition method, continuous wavelet transform (CWT) and Bi-LSTM based classifier. The fifth-order tensor contains the information of the lead, beat, mode, frequency and sample. The fifth and final contribution of this thesis proposes a projection-based multivariate empirical Fourier decomposition (PMVEFD) technique for the decomposition of non-stationary multi-channel signals. The Proposed PMVEFD technique is used to detect atrial fibrillation (AF) in 12-lead ECG signals. The chirplet transform (CT) is used for the time-frequency-phase analysis. A sixth-order tensor containing the information of the lead, beat, mode, frequency, phase and sample is formulated. The tensor domain features extracted after MLSVD are classified by the ensemble learning-based classifier into healthy and AF patients.

In summary, the primary objective of this thesis is to propose an accurate framework for cardiac abnormalities detection in 12-lead ECG using higher-order tensor-based machine learning and signal processing techniques. This tensor-based method enables the implementation of a patient-specific framework in which multiple signal-processing techniques can be used to extract the maximal amount of information from a 12-lead ECG recording of a patient. The framework based on higher-order tensors proposed in this thesis may be applied to other non-stationary multichannel data.