Chapter 14
Heart Sound Data Acquisition and Preprocessing Techniques: A Review

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ABSTRACT

Heart sound or phonocardiogram (PCG) signal quantifies the information about the mechanical activity of the heart, and the medical practitioners use the stethoscope to listen to this sound. The PCG signal can be used for clinical applications such as detection of various valvular diseases and non-clinical applications such as biometric system, stress and emotion detection, etc. The PCG signal acquisition and preprocessing are important tasks for the diagnosis of heart valve-related disorders and other applications. The heart sound preprocessing techniques include denoising of PCG signal, segmentation of first and second heart sound (S1, S2) and other heart sound components from the PCG signal, feature extraction from the segmented heart sound components, followed by classification. This chapter reviews the state-of-the-art approaches for heart sound acquisition and pre-processing techniques and also provides the information that is commonly used by the researchers for the validation of their PCG signal processing algorithms.

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INTRODUCTION

Cardiovascular diseases (CVDs) are the class of ailments which mainly occurs due to the abnormality in the conduction process of the heart, the defect in the heart valves and the heart muscle related disorders (Benjamin et al, 2018). Heart valve related disorders, coronary heart disease and stroke are the most common forms of CVDs which create a major risk factor for heart disease in the United States (US) and other countries (Heart Disease: Facts, Statistics, and You, 2019). Over 17.7 million people die annually from CVDs and this number will grow according to the American Heart Association (AHA) (Benjamin et al, 2018). Heart is one of the most important organ of the human body. It has four chambers (left atrium, right atrium, left ventricle, and right ventricle) and four valves (tricuspid valve, mitral valve, aortic valve, and pulmonic valve) (Jiang & Choi, 2006). The electrical activity of the heart is represented graphically through the ECG signal whereas the mechanical activity of the heart is studied from the PCG signal. Heart sounds are generated from the mechanical events of the heart activity which occurs during the cardiac cycle such as closure of valves, vibration in the walls of the cardiac chambers, turbulence and leakage in the flow of blood (Malanga, 2007). The first heart sound (S1) and second heart sound (S2) are observed in PCG signal during the closure of mitral and tricuspid valves and closure of pulmonary and aortic valves, respectively.

The characteristics of the PCG signal will be different for different valvular heart diseases and it can be used as an early identifier for the detection of diseases such as aortic stenosis, mitral stenosis, aortic regurgitation and mitral regurgitation (Unger et al, 2016). If the valve is not opening properly then this pathological condition is termed as stenosis. Similarly, improper closing of the valve is called regurgitation (Iung et al, 2003). The aortic stenosis (AS) pathology is the narrowing of aortic valve due to the calcification of the valve leaflets and it can progress vary rapidly causing left ventricular hypertrophy which further leads to sudden cardiac death (Unger et al, 2010). Similarly, the aortic regurgitation (AR) occurs when the aortic valve doesn’t close properly and it causes the backward flow of the blood into the lower chamber of the heart (Goldbarg et al, 2007). In mitral stenosis (MS), there is a reduction in the flow of the blood due to the narrowing in the opening of the mitral valve (Bonis et al, 2012) and such condition leads to an increase in the volume and pressure of the blood in the left atrium of the heart. Mitral regurgitation (MR) is a condition in which the valve between the upper left heart chamber (left atrium) and the lower left heart chamber (left ventricle) doesn’t close tightly, allowing blood to flow backward into the left atrium (Unger et al, 2010). The possible causes of MR include rheumatic fever, heart attacks, abnormality of the heart muscle, and atrial fibrillation (De Bonis et al, 2012).

Cardiac auscultation is one of the most fundamental screening tools for clinical diagnosis of heart valve related disorders in primary health care (Sharma, 2015). Before nineteenth century, the physicians used ‘direct auscultation’ for examining the conditions of heart valve by listening to the sound directly from the patient’s chest through ear (Mondal et al, 2013). The acoustic instrument, Stethoscope was invented by french physician Laennec in 1816; since then, ‘indirect auscultation’ becomes possible (Zhang et al, 2016). In the last two decades, due to the advancement of digital technology, the Computer aided diagnosis (CAD) based diagnostics systems have been used to assist medical practitioner for accurate diagnosis of heart disease (Simon et al, 2012). Different signal preprocessing operations such as the de-noising of PCG signal, segmentation of heart sounds, feature extraction from the segmented sounds and