Abstract

Worldwide, Cardiovascular Diseases (CVDs) have been and continue to be the largest cause of death and heart valvular disease is one of the fast growing CVDs. Valvular diseases are manifested in heart sound signals. The major problem with CVDs is that their symptoms occur at a later stage of the disease where it becomes difficult to cure. For early stage detection, a system should be capable of providing adequate signatures in real-life scenarios so that it can be used at home or at workplaces. Such features of the system would be convenient for the user to have frequent monitoring of the heart without a need to visit hospitals. Keeping such advantageous features in view, the thesis work focuses on the processing of the heart sound signal to monitor the cardiac functions in real-life scenarios.

Phonocardiography (PCG) and Seismocardiography (SCG) are the two existing systems for the analysis of heart sound signal. PCG uses a sensor called stethoscope to measure the acoustic sounds produced by the movement of the heart valves. On the other hand, SCG uses a sensor called accelerometer to measure precordium vibrations. SCG has superiority over the PCG in term of the convenience to wear for long-term because of small size and low weight of its sensor. However, both the signals are vulnerable to environmental noises as well as noises generated due to the motion of the subject and noise generated due to movement of other organs such as lungs. In literature, various denoising methods have been proposed to address such issues with the PCG and SCG systems, but separately. The performance of both the systems in the presence of noise is crucial to show their applicability in real-life scenarios. Therefore, the performance of both the PCG and SCG systems are analysed simultaneously in various real-life scenarios. The obtained results show that the SCG is more robust to noise as compared to the PCG. Besides the observed robustness of the SCG, there is a significant scope to improve its performance under such noises. For this, a Discrete Wavelet Transform (DWT) based denoising algorithm is proposed that thresholds the wavelet coefficients adaptively, according to the level of noise. The level of noise present in the signal is measured with a new statistical parameter, med_{75}, that is based on the fact that the summation of the length of the fundamental heart sounds, S1 and S2, remains less than 25 % of the length of a cardiac cycle. To further improve the performance of the algorithm, a non-linear mid threshold function has been presented. It is observed that the SCG signal gets contaminated due to presence of footstep signature when the system is used while walking. To address such cases, an algorithm is developed to remove these signatures by uses of multiple axes accelerometer.

However, the above-mentioned denoising method has limitations of suppressing murmur and hence an algorithm is proposed to address the same. Presence of murmur affects segmentation of heart sound signal. The proposed method uses Tunable Quality Wavelet Transform (TQWT) for the effective segmentation. In this method, the acquired signal is decomposed up to twenty levels only once as compared to approximately 55 times in a recently reported method. This results in 25 times reduction of computational cost of the algorithm. Then a subband is selected based on a quality index, called as Fano factor, from the detailed levels. Objective of exclusion of the approximation level was to reduce the effect of real-life noise. In a recent study, it has been reported that the real-life noises dominate in the low frequency bands.

The work also explores the use of SCG for the assessment of electromechanical (E-M) window which provides an early marker of several CVDs. A portable device has been developed to acquire the electrocardiography (ECG) and SCG signals, simultaneously. The device uses SCG to acquire the mechanical activity of the heart, instead of PCG used in traditional

methods. The developed device is convenient to wear because of the arrangements of the sensors and favourable dimensional features of the accelerometer.

In conclusion, the thesis work has focused to propose a system that is robust against real-life noises and convenient to subject for its long-term use. The system with such features would make it possible to monitor the heart in ambulatory subjects and hence would minimise the unnecessary visits to hospitals. The work can be extended to classify the heart sound signal for specific diseases. Moreover, extreme noise conditions, such as running and jumping conditions of the subject can be considered in noise removal algorithm.

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