ABSTRACT

Phonocardiography is a specialized domain in cardiology in which the heart sounds and murmurs are recorded as time series data and amenable to the visual inspection as well as audio perception. Digital auscultation – art and science of listening and interpreting heart sounds and murmurs using conventional acoustic or electronic stethoscope and is used as primary screening tool of the heart diseases. The heart sounds and murmurs are the acoustic signals that play significant role in auscultation and clinical interpretations of the heart diseases, in particular heart valvular diseases.

With the recent development in digital signal processing techniques and biomedical instrumentation engineering, it is possible to digitize the heart sounds and murmurs using digital stethoscope and can be stored as digital audio objects in the standard digital audio formats (e.g., .wav or .mp3) in a cardiology database. For example, in Texas Heart Institute, USA, the phonocardiographic recordings (e.g., 300 to 400 recordings/day) are performed and stored in the cardiology database as audio objects. When the phonocardiographic signals are viewed as audio objects, the conventional text processing algorithms for indexing, searching, classification are inappropriate and therefore content – based audio processing algorithms and techniques were proposed.

The content based audio retrieval and classification algorithms are more promising for the multimedia objects; in particular audio objects are used extensively in music information retrieval (MIR) applications. The general procedure is to extract the audio feature vectors and map into the vector space model and apply similarity measures and retrieve the results for an audio query using query by example (QBE).

In this research work, a set of audio content-based retrieval and classification algorithms and techniques exclusively for the heart sounds and murmurs are proposed and investigated. This research contributed to the design of content-based algorithms and novel (psychoacoustic distance measure) techniques for the indexing, searching and classification of heart sounds and murmurs. A new audio model for heart sounds and murmurs is proposed and evaluated at the signal level (e.g., time series data – characterizing spectral properties) as well as at higher level abstraction – audio perception of heart sound and murmurs. The modeling of audio at frame, inter-frame
level along with a set of perceptual features vectors (e.g., pitch, thrill, rush, rumble) and facilitate for the easy retrieval and classification of heart sounds and murmurs. In general, cardiologists listen carefully; evaluate the heart sound and murmurs using subjective reasoning based on audio perceptual properties. A set of novel distance measures based “psychoacoustics” features (e.g., pitch, thrill, soft, loudness etc.) were modeled and quantitatively used for the similarity measures. The psychoacoustics based similarity measures and content based retrieval algorithms were compared with the conventional retrieval (e.g., spectral based) and results establish that the psychoacoustics based retrieval improves the efficiency by 70%.

It is observed that audio retrieval algorithms using psychoacoustic features are in synchronization with the doctor’s reasoning with 80 - 85% match when compared with the only spectral properties. On average, it has shown that the MFCC histogram search and retrieval algorithm can achieve a high precision - 97%.

The filtered heart sound signals and murmurs were classified using support vector machine (SVM) technique by varying signal-to-noise ratio (SNR) on reference heart sound and murmur database which contained various types of heart diseases. It is observed that the classification rate is almost 100%. For example, the classification accuracy for diastolic rumble signal is calculated as 320/(320+28+2) = 91.4286%.

Similar results are obtained for other heart sounds and murmurs. Classification plots for different heart sounds and murmurs are reported in the thesis. Discriminatory feature description and an approach for multiclass signal classification based on second-order statistical features are also presented. The 2nd order cumulants of the real and imaginary part of the complex envelope are used as features for multi signal classification. The proposed system is tested on three heart sound and murmur schemes. Two different classifier, Support Vector Machines (SVM) and K-Nearest Neighbor (KNN) classifier are used to classify the heart sound signals. From the results, SVM classifier outperforms the KNN classifier for digital audio signal classification and also it is observed that the classification accuracy of the stenosis scheme for 0 dB is much lesser (i.e. poor) than all other schemes used. Confusion matrix is used to evaluate the performance of the proposed system and the experimental results prove that the proposed system provides satisfactory performance for the multi signal classification.