CHAPTER 2

LITERATURE REVIEW

As a first phase of this research, various literatures relevant to this topic were studied in detail with regard to Computer Applications to the Biomedical Engineering Field in general and Cardiac Sound Signal Analysis in particular.

2.1 LITERATURES ON ADVANCES IN BIO-MEDICAL ENGINEERING THROUGH COMPUTERS AND INFORMATION TECHNOLOGY

Lakshminarayan et al. (1988) have stated that Biomedical computing encompasses virtually every aspect of medical research. Areas such as computer simulations of disease processes, physiological mechanisms, pharmacological interactions and computer analysis of data have made many important contributions to medical research. Orphanoudakis et al. (1988) have stated that Biomedical Technology is currently going through a revolutionary period. The use of computer methods in the analysis and interpretation of medical images, as well as in the proper integration of multi-modality imaging information is one of the major trends shaping the future of medical imaging. He concludes that the diagnostic imaging and medical decision making in general can no longer be served well by conventional computers and sequential processing.

Patterson et al. (1989) have described that the impedance cardiography is the study of cardiac function from the measurement of the electrical impedance of the thorax. He concludes the impedance cardiography
as a simple, low cost, non-invasive method to measure cardiac function, but more basic experimental work is needed on the interpretation of waveforms in order to provide more reliable and meaningful clinical information. Reddy (1989) has suggested that acceptance of technology is needed for good improvements in the biomedical engineering field. Rapid technological advances in other fields will soon lead to new health care concepts such as Computer aided surgery, expert systems for diagnosis and robotic surgical manipulators. He concluded that biomedical engineering discipline has emerged to a point where it can significantly contribute to increased and more efficient health care delivery. The Universities will play a key role in technology transfer by training biomedical engineering students to identify medical problems that can be addressed with technological solutions. Akay et al. (1994) have presented that coronary artery disease can be identified non-invasively by using wavelet-based fuzzy networks by using clinical information variables and extracting useful information from the diastolic heart sounds. Lakshminarayan et al. (1997) have expressed that advancements in medicine and health care are being significantly influenced by the exploding information technology developments. They have discussed that all the “fast-paced” developments are going to influence the practice of medicine, education, health care and research in the future.

The above discussed literatures in the field of advances in the Biomedical Engineering clearly shows the application of computers and information technology in this area. In the next section the different techniques for analysis of the heart functions and its involvement in the cardiology field are discussed.
2.2 LITERATURES ON COMPUTER APPLICATIONS IN CARDIOLOGY

Sarkady et al. (1976) have developed an analysis procedure for small digital computers for the study of heart sounds and heart murmurs in frequency, time and envelope domains. Iwata et al. (1980c) in their paper, have investigated several discriminate methods for phonocardiogram classification. The discriminate method is divided into two main methods. They are parametric method and non-parametric method. They investigated the performances on the classification of both methods for PCG classification. Okada (1982a; 1982b) has talked about the distribution of the heart sounds audible on auscultation, which varied from one subject to another. The sound image could be useful not only for diagnosis but also for educational purposes.

2.3 LITERATURES ON HEART SOUND SIGNAL

Iwata et al. (1980b) have suggested a new algorithm for automatic classification of the phonocardiogram and its experimental results. It is purely based on the frequency domain characteristics, which are analyzed by a linear predictive method together with the time domain characteristics of the phonocardiogram. The algorithm requires high frequency phonocardiogram signal only. Semmlow et al. (1983) have presented a reliable and inexpensive non-invasive procedure for detecting coronary stenosis which is highly useful in diagnosis and treatment of coronary artery disease. In this paper one possible approach to search for sound characteristics of vascular narrowing is discussed. Cohen et al. (1984) have stated the details about the analysis of breath sounds for the diagnosis of pulmonary diseases. In this paper an automatic breath sounds classification scheme is suggested. Types of normal and abnormal breath sound’s are classified, with the goal of providing the physician a diagnostic tool. This classification is performed in two levels; the first level is based on the linear prediction co-efficient and the second level on energy
envelope features. Rangayyan et al. (1988) in their review article elaborately obtained the description of the genesis of the heart sound signal and the characteristics of the phonocardiogram signal, followed by a review of various signal processing techniques. In his paper he states that the major advantage of phonocardiography is that it is totally passive and non-invasive involving no external radiation.

Durand et al. (1994) have given the detailed review of the most recent developments in instrumentation and signal processing of digital phonocardiography and heart auscultation. They said that the digital phonocardiography and heart auscultation are useful for enabling experimental verifications of certain modeling hypothesis on heart sound genesis and their usefulness for the study of the distribution of native and prosthetic valve sounds on the surface of the thorax.

2.4 LITERATURES ON APEXCARDIOGRAM SOUND SIGNAL

Aronow et al. (1971) have presented the study report of the apaxcardiogram taken from the specimens, under treadmill test. Various apaxcardiogram signals and its features are also used. Parker et al. (1971) have suggested that the apaxcardiogram may also be used in the assessment of left ventricular disease. In the apaxcardiogram a wave may be seen at the late diastolic response of the left ventricular to atrial systole. Park et al. (1973) have discussed the systolic time intervals in infants with congestive heart failure by using apex cardiogram signal.

Gibson et al. (1974) have presented a study report to determine whether the ‘A’ wave of the apex cardiogram, a reflection at the late diastolic response of the left ventricle to atrial systole, corresponded in a quantifiable way to left ventricular late diastolic stiffness or not.
2.5 LITERATURES ON THE POWER SPECTRAL STUDY IN CARDIOLOGY

Bogert (1967) has explained that the two important considerations in the use of computer for power spectrum analysis are the availability of a set of sub programs to perform the necessary functions and an adequate display of the output. In this article the author relates this consideration to his experiences using a digital computer to investigate the echo analysis. Welch (1967) has clearly discussed in his article, the necessity of using the Fast Fourier transform in power spectrum analysis. The principal advantage of this method is reduction in the number of the computations and required storage. This method also involves sectioning the record and averaging modified periodograms of the sections.

Yoganathan et al. (1976a; 1976b; 1976c) have stressed that the important diagnostic information might be obtained from frequency studies of heart sound. Such studies should increase the clinical importance of phonocardiography. They have suggested that the Fast Fourier transform is a powerful technique, which facilitates the analysis of signals in the frequency domain. In this paper the author has discussed the important features of the Fast Fourier transformations which are relevant to its increasing application with respect to biomedical data. In this paper, how the important diagnostic information can probably be obtained from frequency analysis studies of cardiovascular sounds and how they will help in understanding the basic mechanisms which produce the sounds are discussed.

Iwata et al. (1977) have reported some results with phonocardiogram pattern classification. Linear prediction analysis technique is applied to extract the spectral pattern from phonocardiogram signals. The efficiency of the spectral features for phonocardiogram has been confirmed experimentally.
Hearn et al. (1979) have discussed the heart sound of human and animals. Spectral analysis of small time segments of the first heart sound is carried out by means of a spectrograph analyzer. Iwata et al. (1980a) have developed a new algorithm for detecting the first and the second heart sounds by spectral tracking. The algorithm uses low frequency spectral tracking for time series of the phonocardiogram. It also tracks the spectral level smoothly so that it is fairly effective for the detection of heart sounds. Gavriely et al. (1981) have used the Fast Fourier Transformation to carry out an objective and accurate measurement and characterization of breath sounds. Chowdhury et al. (1981) have introduced a new method to find the spectral analysis of respiratory sound using the technique of Fast Fourier transform. The author suggested that this type of studies may prove to be a promising noninvasive diagnostic tool for lung diseases and increase clinical importance of lung auscultation.

Nandagopal et al. (1984) have applied a new spectral analysis technique using selective linear prediction coding based on a pole model to determine the spectral distribution of second heart sounds in normal children. The selective linear prediction spectrum is compared with the conventional spectrum obtained using the Fast Fourier transformation technique. It is observed that the selective linear prediction method produces better definitions of spectral peaks. Myers et al. (1986) described the power spectrum analysis of heart rate variability and compared with four other reported methods with respect to their efficacy as predictors of risk of sudden cardiac death. Finally he has suggested that the power spectrum analysis appears to be more effective than the other methods. Durand et al. (1990a) have described the system model based on the simultaneous recording and analysis of the intra cardiac and thoracic phonocardiograms to estimate the time varying properties of the heart/thorax acoustic system of the dog. Spectral analysis and acoustic
transmission of mitral and aortic valve closure sounds in dogs were clearly discussed.

Semmlow et al. (1990) have suggested a new approach to detect coronary artery disease non-invasively and to identify the features associated with turbulent blood flow in partially occluded coronary arteries by the analysis of isolated heart sounds. Bianchi et al. (1990) have described spectral parameters which seem to be sensitive enough to discriminate between normal and diabetic subjects with or without neuropathy on the basis of external criteria with respect to the experimental protocol.

Jamous et al. (1992) have given the optimal duration of the time window to be used for computing the time frequency representation of thoracic measurement of the PCG. They have also reported that the optimal range of the time window duration is between 16 and 32 ms. Durand et al. (1993; 1994) have discussed the diagnostic performance of the two spectral techniques (the Fast Fourier Transform and Auto Regressive modelling) combined with four windowing functions and two classifiers to detect valvular degeneration. This study shows that reliable diagnostic information about the status of bioprosthetic valves can be extracted from the spectrum of the heart sounds. They have given a detailed review of work done towards the application of signal processing of heart valve sounds for the detection and qualification of prosthetic valve degeneration and dysfunction. In this paper he has suggested that digital signal processing of prosthetic valve sounds is an interesting and promising approach for designing a low-cost instrument for noninvasive detection of prosthetic valve degeneration.

Markus (1995) has given a study report stressing on the importance of processing speed and FFT time-window overlap using embolic signals recorded from patients which are subsequently analyzed in standard Transcranial Doppler Machines. Mitor et al. (1998) has proposed an approach
for more systematic comparison of the most widely used heart rate variability spectra. The similarities and diverging properties of the spectrum of counts, the instantaneous heart rate spectrum and the interval spectrum are explained, based on the established generic relationships of their respective input signals. Satish (1998) has explained a novel approach of short-time Fourier transform and wavelet transform for fault detection during impulse testing of power transformers. The neutral and/or capacitively transferred currents which are recorded during an impulse test can be directly analyzed with this approach. All the previous research work in this spectral study of cardiac signal can give us the required very good information and new ideas to find out a solution to the unresolved problems. Here one such unresolved problem is selected and solved using new techniques.

2.6 LITERATURE REVIEW IN THE AREA OF SPECTRAL STUDY OF CARDIAC SIGNALS BY PARAMETRIC MODELING METHOD

Gersch et al. (1973) have given the results of an empirical study of the application of Akaike’s final predictor error criterion to the estimation of the order of finite auto regressive models. Kwok (1979) has presented a summary on the evaluation of the auto regressive technique applied to spectral analysis of physiological signals from the gastro-intestinal tract. This work gives the detailed study report of the various model parameters and their importance to a successful modeling process. Model order selection for AR modeling spectral analysis of physiological signals are clearly discussed. Sakai (1979) has investigated several statistical properties of the auto regressive spectral analysis method by using the periodogram technique. Kwok et al. (1980) have clearly discussed the auto regressive modeling techniques for the analysis of periodic signals in addition to the Fast Fourier Transform Methods. The success of an auto regressive model however, hinges on the choice of the model order. Final prediction error scheme offers an excellent approach to model order selection
but it suffers from high time complexity. Friedlander et al. (1984) have given a detailed information and application of modified Yule–Walker method by AR and ARMA modeling spectral study. He has also proposed some new features for the modified Yule-Walker method.

Akay et al. (1990a; 1992) have presented the study report on AR modeling of diastolic heart sound segment investigation by using both a gradient lattice and recursive least-square lattice predictor. The information gained from either the AR spectrum (or) the zero’s of the prediction co-efficient is independent of other non-invasive clinical tests and potentially could be used in combination with these tests to achieve improved non-invasive diagnostic capability. They have also aimed to improve signal-processing techniques to identify the additional signal components found in heart sounds of patients with coronary artery disease. The added components form the basis of our approach for non-invasive detection of coronary artery disease.

Bianchi et al. (1992) have described the different approaches based on parametric AR models for the analysis of heart rate variability signals and its relationship with respiration. The improved extraction of parameters of clinical interest may not only depend uniquely on the powerfulness of the algorithm but also on its correctness in application. In this work the authors have clearly shown how different clinical and physiological problems can be solved by means of the correct application of the AR models. Akay et al. (1993) have given a detailed study report about the spectral study of the cardiac sound signal for finding coronary artery disease. Different results obtained using four major signal processing techniques are compared on the basis of the results. The Eigen vector method showed the best diagnostic performance than the other three methods namely FFT, AR and ARMA. Arnold et al. (1998) have given an adaptive on-line procedure for auto regressive modeling of non-stationary multivariate time series by means of Kalman filtering.