CHAPTER 9

CONCLUSION

9.1 SUMMARY OF THE THESIS

The primary function of the cardiovascular system is to pump blood throughout the body to supply oxygen and nutrients to the cells, remove cellular waste and maintain homeostasis. Heart diseases lead to functional impairment of this system. The assessment of the type of heart disease and degree of functional impairment of the cardiovascular system is extremely important in the diagnosis, management and prognosis of cardiac disorders. Since heart diseases are life-threatening, there is a growing need for newer and reliable techniques that can support physicians in speedy diagnosis to save lives. In pursuit of this need, this thesis addresses certain investigations performed for enhancing the diagnosis of cardiac diseases.

An electrocardiogram is the primary, non-invasive tool used by physicians for diagnosing cardiac arrhythmia. Detection of abnormal ECG signals is a critical step in administering aid to patients. To cater to large number of patients, to eliminate subjective inaccuracies and to aid the physician in the diagnosis, several methods for automated arrhythmia detection have been developed in the past. In clinical domains, one has to face the problem of developing classifiers that are able to deal with nonlinear discrimination between classes and suppression of false alarms. In this direction a new approach has been developed for arrhythmia classification based on Random Forests and Logistic Model Tree classifiers. Discrete Wavelet Transform (DWT) has been used to decompose the ECG signals of
11 different arrhythmia types and extract the characteristic wave points. Intervals between these characteristic wave points were obtained. Using these intervals, a set of time domain, frequency domain and nonlinear parameters were derived. A data set developed using these parameters and the corresponding output class (type of arrhythmia) was used for evaluating the performance of these classifiers. The results indicate their effectiveness for classification of cardiac arrhythmias. Their classification performance is comparable with the other methods cited in the literature. Parameters derived from ECG features and RR interval time series can therefore be used as a reliable indicator of different types of arrhythmias. The proposed classifiers, after validation by experts, can serve as a diagnostic tool and aid the physician in the detection and classification of cardiac arrhythmias.

Heart Rate Variability (HRV) analysis, a non-invasive technique, has gained prominence in the field of cardiology for detecting cardiac diseases. Since disease symptoms occur at random and do not show up all the time in an ECG, there is a need to study the ECG over a longer period. For this purpose the heart rate variability signal is used. The time interval between the successive R-peaks (RR-interval) of the ECG signal plotted against the time scale provides the HRV signal. A new approach for classification of cardiac diseases based on HRV using linear and nonlinear measures has been proposed in this thesis work. DWT decomposition has been used on ECG signals of different disease types to obtain RR interval data. HRV analysis was performed on this data and a set of linear and nonlinear measures were derived. Three classifiers, namely, Random Forests, Logistic Model Tree and Multilayer Perceptron were used and the classification performance studied separately using linear measures, nonlinear measures and combined measures. The Multilayer Perceptron classifier outperformed the other two classifiers in all the three types. The results indicate that higher classification accuracy can be achieved combining both linear and nonlinear measures. The results
obtained by this approach are comparable with those obtained with other techniques cited in the literature. This study also reveals that both linear and nonlinear measures need to be considered for a better understanding of the behaviour of the cardiovascular system.

Heart auscultation is a non-invasive, screening technique used as a primary tool in the diagnosis of heart disorders. The conventional method of auscultation with a stethoscope is a subjective process that depends on the physician’s experience and ability to differentiate between different sound patterns. For an objective assessment of heart sounds for diagnosis of cardiac disorders, the only reliable method is digital recording and subsequent analysis. In this study, a new approach based on wavelet transform and artificial neural networks has been proposed for classifying heart murmurs into eight types viz., normal, early systolic, mid systolic, late systolic, holosystolic, early diastolic, mid diastolic and late diastolic. DWT has been used to decompose the heart murmur signal into subbands and the wavelet coefficients obtained were used to derive a set of 15 features. Using these features as input, two-layer feedforward neural network models with backpropagation were developed with different combinations of training algorithms and activation functions to classify the heart murmurs. The neural network with Levenberg-Marquardt training algorithm and tansigmoid activation function yielded the best performance. The results also demonstrate the capability of the developed system as a support tool for physicians in the computer-aided diagnosis of heart murmurs.

Computer-aided automatic ECG analysers can aid physicians in speedy and accurate diagnosis of heart diseases. A novel rule-based ECG analyser has been developed in this research work. The ECG XML file from the electrocardiograph is used as input to this system. The measurements of the 12 leads of the ECG are extracted from this ECG file of the patient. An
inference engine identifies the rule in the rule base that best matches the lead measurements and displays the associated abnormality. Philips XML to SVG converter software is used to display the ECG waveform. Database connectivity is provided for storing post diagnostic information for future reference. Access to this database also facilitates addition and modification of rules. The ECG analyser was tested with 127 ECG XML files collected from PSG Institute of Medical Sciences and Research hospital, Coimbatore. The results were found to match well with the expert’s diagnosis.

The knowledge of an expert is largely confined to him and is not freely available for decision making. Computer based expert systems are now developed focussing on emulating the decision making capabilities of human experts. Further, the complexity involved in medical diagnosis and the shortage of medical experts have also led to the development of expert systems in the field of medicine. Recognizing this need three different expert systems have been developed for a) chest pain diagnosis b) ECG analysis and c) IHD diagnosis. Inputs normally used by physicians for diagnosis are used to develop rules and a rule base is developed for these expert systems. An inference engine identifies the rule in the rule base that best matches the inputs and displays the associated abnormality. Database connectivity is provided for storing post diagnostic information for future reference. Access to the database also facilitates addition and modification of rules. Test runs were conducted with these expert systems and the results found to tally well with the diagnosis of cardiologists. These experts systems can support physicians in their diagnosis.

Telecardiology benefits cardiac patients by enabling treatment from a distant place. Rural health centres lack adequate facilities and availability of expert cardiologists. To address this need telecardiology frameworks have been developed. The existing systems have their merits and applications.
However, they lack the involvement of expert cardiologists in the diagnostic process. The proposed user-friendly web based telecardiology framework, besides addressing this issue, provides a cost effective scalable solution for bringing quality health care to the rural sector. The rural centre needs to have only a PC with a web browser installed and a network connection. This framework facilitates patient diagnosis by an expert via the internet, in a centralized way, without the need to run programs on the local stations. Clinical information and ECG waveforms are routed from the rural centre to the expert for diagnosis via the server. Diagnostic results from the expert are routed back to the rural centre via the server. The server stores the diagnostic results of patients for future reference. The system was configured both in the LAN and in the internet environments and was found to work satisfactorily. Implementation of this framework by hospitals with rural centres can change the way health care is delivered in cardiology for rural patients.

Teleconsultation frameworks provide tools for establishing meaningful communication between physicians for diagnosis. The current frameworks available for teleconsultation allow image manipulation and voice communication. However they do not support video consultation. For diagnosis of complex diseases, doctors need dynamic image manipulation with voice communication and video consultation facilities. The existing internet based teleconsultation models fail to provide all these features in one. The proposed system supports both image and video based consultation, with voice communication facility. In addition to this, direct connectivity to patients with an image acquisition system through IP based communication help experts acquire images for offline consultation between them and on-line consultation with patients. The entire framework has been designed to work in an open source environment across the internet, leading to cheaper implementation and maintenance cost.
9.2 SUGGESTIONS FOR FUTURE WORK

The research work presented in this thesis can be extended further as suggested below:

(i) Data for other arrhythmia types and cardiac diseases can be collected and classification attempted using the proposed classifiers. The performance of these classifiers can also be studied using real time patient data from hospitals to validate the observations.

(ii) The expert system developed for chest pain diagnosis is a fairly good diagnostic tool, though it is not a complete product to be released for general use. A full-fledged expert system would be one that includes clinical information. This exercise can be taken up as future work.

(iii) There are limited studies made on heart rate variability at rest and during exercise and their prognostic significance. Further research can be taken up in this area and the findings can help augment the power of the exercise test in risk stratifying IHD patients.

(iv) PACS is widely used in hospitals. The teleconsultation framework can be extended allowing the clients to connect and access their hospital’s PACS server.

A desktop application can be developed to alert an offline physician by sending a message to the physician’s personal computer or mobile phone.

Most of the internet based collaboration techniques support video conferencing. Java Media Framework provides real time sessions for video conferencing. This teleconsultation framework can be extended for video conferencing using this feature.