CHAPTER 1

INTRODUCTION

1.1 NEED FOR THE RESEARCH

The need for a device that continuously monitors the health of an individual arises, when the person interested in monitoring desires to be informed of the health status as soon as a critical condition is observed, to provide the appropriate remedy immediately. Generally a patient in Intensive Care Unit (ICU) will be continuously monitored and vital signals like Electrocardiogram (ECG), Photoplethysmogram (PPG) and temperature are recorded for 24 hours. The information from the recorded PPG and ECG signals can be used to calculate the blood pressure, diagnose cardiac abnormalities and monitor cardiac risk if any, by analyzing the obtained signals using various algorithms for the improvement of the health care in hospitals.

1.2 SIGNIFICANCE OF THE WORK

Noninvasive measurement of blood pressure is needed when a parent wants to monitor the health of a child with cardiac disorder or when a doctor needs to study how a patient’s health condition varies in a period of few days. It is sometimes more important to assess the health status based on trends in the BP and pulse rate readings. A BP reading decreasing in a short period of time would suggest that the patient is going into shock. A long term trend of BP values may be required to assess if the patient is experiencing
hypertension. Blood pressure is the most often measured and the most intensively studied parameter in medical and physiological practice. Blood Pressure measurement techniques are basically put into two classes: direct and indirect (Yuan-ting Zhang 2004). The direct method can obtain BP continuously and accurately, but it is invasive and has the danger of infection. The indirect techniques are non-invasive, with improved patient comfort and safety, but needs cuff at the expense of accuracy. They measure the pressure only at a single point of time and are not accurate enough. Bazzett and Dfeyer (1994) had found that pulse wave velocity (PWV) is related to BP and also to the flexibility of the arteries. Blood pressure (BP) is the function of cardiac output which is the amount of blood volume output per cycle. BP is directly proportional to the rate at which the blood travels in arteries and flow rate is calculated from pulse wave velocity (PWV).

Thus, PWV could be a useful parameter for continuous monitoring of blood pressure. However, it is difficult to measure pulse wave velocity. So it can be replaced by pulse transit time (PTT) and can be related to BP. Lansdown et al (1957) showed that the relation between PTT and BP in physiology is linear, and the relation is steady for individual during certain time. If BP increases, PTT decreases and vice versa. As pulse rate is approximately same as that of heart rate, it can be measured from PPG signal which is a simpler process than measuring heart rate from ECG which has more complexity in electrode placement. The existing BP devices are mainly cuff based that are bulky, inconvenient to carry and do not allow for BP value to be obtained in a beat-by-beat manner. Therefore, a cuff-less and non-invasive method is desirable that allows continuous BP measurements to be made.

Studies have reported an association between arterial function indices and cardiovascular risk factors, as well as the risk of incident
cardiovascular events, including coronary heart disease and stroke (Eshan Patvardhan et al. 2011). The analysis of peripheral blood volume pulse helps to understand arterial pathologies, a major contributor to cardiovascular diseases, which is a common cause of death in modern society. The risk factors for cardiovascular diseases are associated with the increasing stiffness of the arterial wall. At present there are various instruments that measure augmentation index such as Peripheral Arterial Tonometry (PAT-AIx), SphygmoCor, version 7.1, AtCor Medical, CVProfilor device, Diagnostic Applanation Tonometry (Specaway) and Tensiomed Arterioraph (Ali Khoshdel et al. 2010). The usual charge for the testing with these instruments itself is about $250 per test. Photoplethysmogram is a measure of the volume of the blood in the vessel. Thus by analyzing this peripheral pulse wave cardiovascular risk can be predicted and by using the proposed algorithm, blood pressure can be calculated non-invasively from a PPG signal.

Electrocardiogram also known as ECG is a method of recording the electrical activity of the heart. Each heart beat is caused by a section of the heart generating an electrical signal, which then conducts through specialized pathways to all parts of the heart. These electrical signals also get transmitted through the chest to the skin where they can be recorded as a graph. Understanding the various waves and normal vectors of depolarization and repolarization is very important to obtain useful diagnostic information. ECG signals have a wide array of applications throughout the medical field in determining whether the heart is functioning properly or suffering from any abnormalities.

A normal ECG trace consists of a P wave, QRS complex, ST segment and a T wave. The P wave is the electrical signature of the current that causes atrial contraction. The QRS complex corresponds to the current that causes contraction of the left and right ventricles. The T-wave results
from the current generated during rapid repolarization of the heart. ECG waveform may contain important pointers to point the nature of diseases afflicting the heart. Several algorithms have been developed in the literature for the detection and classification of ECG pattern. The most difficult problem faced by today’s automatic ECG analysis is the large variation in the morphologies of ECG waveforms, not only of different patients or patient groups but also within the same patient. The ECG waveforms may differ for the same patient to such extent that they are unlike to each other and at the same time alike for different types of beats.

The Fourier transform is a tool widely used for many scientific purposes, but it is well suited only to the study of stationary signals where all frequencies have an infinite coherence time. The Fourier analysis brings only global information which is not sufficient to detect compact patterns. Gabor introduced a local Fourier analysis, taking into account a sliding window, leading to a time frequency-analysis. This method is only applicable to situations where the coherence time is independent of the frequency. This is the case for instance for singing signals which have their coherence time determined by the geometry of the oral cavity. Morlet introduced the Wavelet Transform in order to have a coherence time proportional to the period.

The wavelet transform or wavelet analysis is probably the most recent solution to overcome the shortcomings of the Fourier transform. In wavelet analysis the use of a fully scalable modulated window solves the signal-cutting problem. The window is shifted along the signal and for every position the spectrum is calculated. Then this process is repeated many times with a slightly shorter (or longer) window for every new cycle. In the end, the result will be a collection of time-frequency representations of the signal, all with different resolutions.
The analysis of the ECG has been widely used for diagnosing many cardiac diseases. Most of the clinically useful information in the ECG lies in the intervals and amplitudes defined by its features (characteristic wave peaks and time durations). The development of accurate and quick methods for automatic ECG feature extraction is of major importance, especially for the analysis of long recordings (Holters and ambulatory systems). Developing an algorithm for the detection of the P wave, QRS complex, ST segment and T wave in an ECG is a difficult problem due to the time-varying morphology of the signal when subjected to physiological conditions and in the presence of noise. In this work wavelet based techniques are used for its less computational time and better accuracy for classification, characterization and analysis of various ECG characteristic points.

There are several characteristics which comprise a cardiac cycle, the first being the P wave, which represents the initial pacemaker pulse of the cycle and the propagation of this pulse through the atrial tissue mass. The P wave can be difficult to discern in some cases, especially elderly patients and this has led to it being overlooked in practical cardiology and automated analysis. Abnormalities in the P-wave may be produced by structural changes, such as left atrial enlargement (LAE), or inter-atrial block (IAB). LAE has been significantly linked to a host of pathological conditions and complications such as long-term and permanent atrial fibrillation, atrial thrombus and embolic stroke. IAB has been shown to be significantly prevalent in patients who suffer from embolic strokes. Such atrial conditions can produce significant alterations to the electrical signature of atrial activity. The dispersion of atrial conduction and the use of P-wave signal-averaged ECG have been shown to be reliable clinical predictors after surgery, forewarning the onset of arrhythmic atrial conditions.
The development of accurate and quick methods for automatic QRS complex feature extraction is of major importance, especially for the analysis of long recordings. In fact, Beat detection is necessary to determine the heart rate and several related arrhythmias such as Tachycardia, Bradycardia, etc. The QRS complex feature extraction system provides fundamental features to be used in subsequent automatic analysis.

The ST segment connects the QRS complex and the T wave. Ischemic heart disease (IHD) or myocardial ischemia is a disease characterised by ischemia (reduced blood supply) to the heart muscle, usually due to coronary artery disease can be detected by the ST segment analysis. Its risk increases with age, smoking, hypercholesterolemia (high cholesterol levels), diabetes and hypertension (high blood pressure) and is more common in men and those having close relatives with ischemic heart disease.

To detect heart disease, physicians inspect ECG for the existence of abnormal patterns like irregular beat, interatrial block, ST level change and morphological change and so on. However, bio-signals being non-stationary the reflection may occur at random in the time-scale (that is, the disease symptoms may not show up all the time, but would manifest at certain irregular intervals during the day). From the practical point of view, for the effective diagnostics, the study of ECG pattern and heart rate variability signal may have to be carried out over several hours. The volume of the data being enormous, the study is tedious and time consuming and the possibility of the analyst missing the vital information is high. Hence, computer based analysis and classification of diseases can be very helpful in diagnosis.
1.3 SCOPE OF THE WORK

This work estimates blood pressure and pulse rate simultaneously which are the critical parameters of cardiology. Here blood pressure is estimated from the pulse transit time using wavelets and wavelet based peak detection algorithm is used for the calculation of pulse rate from PPG. This work also finds the cardiac risk of a patient from a Photoplethysmographic Signal. It is important to determine the cardiac risk of a patient in advance to prevent premature death. Augmentation Index is an important factor of cardiovascular risk. The augmentation index is determined by implementing an algorithm in MATLAB for stationary signals and further extended to measure AI in real time signals using LabVIEW.

This work also helps in analysing ECG signals by extracting P wave, QRS complex, ST segment and T wave which helps in diagnosing various cardiac abnormalities. A large number of techniques exist in the literature for the automatic detection and classification of ECG patterns. These include the use of Time Domain Approaches, Artificial Neural Networks, Principal Component Analysis, Fuzzy and Neuro-Fuzzy Systems etc. The use of wavelets for analysis and classification of biomedical signals, including some components of the ECG, are well documented in literature (Mahmoodabadi et al 2005). Wavelets offer an important information-rich parameterization method for data reduction of the ECG time-series (Saritha et al 2005). Recently, of the number of techniques proposed to detect these features, this procedure using discrete wavelets proved to be one among the best.

The main aim of the work is to develop this as a practical tool and to prove that an inexpensive routine test can diagnose diseases, estimates blood pressure, pulse rate and heart rate and provide early warnings to major cardiac conditions, thus saving the significant cost of health care system significantly.
1.4 ORGANIZATION OF THE THESIS

The thesis is organized as follows. Chapter 1 provides a brief introduction to the area of research and the motivations to do the research. In Chapter 2, a detailed review of literature is presented on the various methods related to the research work. Chapter 3 gives an overview of the wavelet transform, Electrocardiography and Photoplethysmography principles. Chapter 4 describes the methodology that has been proposed to estimate blood pressure, pulse and heart rate. Chapter 5 elaborates the methodology that has been proposed to analyse pulse wave to predict the cardiac risk of a person. Chapter 6 describes the methodology used for extraction of characteristic points of an ECG signal for diagnosing cardiac abnormalities. Chapter 7 presents the conclusions from the work done in this research and outlines areas requiring further research.