CHAPTER I

INTRODUCTION

1.1 PHYSIOLOGICAL SIGNAL PROCESSING

Computer aided analysis of the physiological signals like ECG (electrocardiogram), and EEG (electroencephalogram) is recognized as an effective clinical diagnostic tool in the physiological measurement field. Analysis of the noninvasive investigative parameter ECG is one of the most extensively studied fields to extract important information about clinical condition of the cardiac patient. An ECG represents the heart’s electrical response captured by skin electrodes from body points displaying respective potential difference and is constituting of P-wave, set of QRS-waveforms and T-wave. The ECG signal is a very low amplitude signal of about 10 microvolt with frequency range lying between 0.5Hz to 100Hz. The morphological (shape and size related) and temporal (durations/segments) parameters of the ECG waveform represents the overall functionality of the heart and thus reflects the state of cardiac health. Each ECG signal record is inspected for both temporal and morphological parameters and is characterized. These parameter values have been standardized for normal human heart. Any deviation from these standardized values of ECG signal parameters due to variation in normal heart rhythm or change in ECG signal morphology represents a state of heart dysfunction, which can be detected by analysing the input ECG signal. Thus, ECG has become the most common and inexpensive clinical diagnostic tool to recognize human physiology and in turn helps in providing subsequent and timely therapy of the related cardiac diseases. Early detection and relative treatment of cardiac diseases are extremely crucial as it can prolong life and can prevent sudden death of the patient. Each heartbeat consists of distinct cardiac events which can be characterized by distinct time domain and frequency domain features in the ECG waveform. The amount and nature of captured deviations in the recorded ECG from normal rhythm provide significant clinical information. For precise recognition of distinct cardiac abnormalities, it is important to capture and characterize these deviations in temporal and morphological parameters of
ECG signal accurately. However, these corresponding subtle variations in ECG rhythm are difficult to analyse visually by naked human eye. Hence computer assisted analysis and classification of cardiac diseases can help cardiologists to monitor subject’s cardiac health efficiently at early stage. Automated analysis of ECG signals has been extensively used in the diagnosis of many cardiac diseases like ischemia, arrhythmias, and myocarditis, or heart rhythm disorders and for monitoring drug effects or pacemaker activity. Therefore, ECG beat classification for automated detection and classification of human cardiac states is very useful in healthcare technology, as it will help the doctor to diagnose and act faster in case of emergency conditions.

Like analysis of ECG provides a lot of information about the human physiology through its patterns to diagnose cardiac disorders. Similarly, the use of EEG has become more extensive for the development of brain-computer interfaces (BCI) to include areas like lie detection, stress, and emotion measurement. This sparked some interest in investigating whether an emotion could be recognized merely seeing the physiological response. People can hide their emotions from outside appearances such as altering the pitch of speech and hiding facial expression. However, they cannot hide their emotions in physiological signal responses. This led to the development of emotion detection methods based on human physiological signals such as heart rate, skin conductance, cardiac activity, neural responses, etc. Recent research reveals that monitoring of EEG signals has also been proven to be an effective and promising tool to analyze the human neural responses in the context of emotion detection. An EEG signal represents brain’s neural responses. A typical EEG signal has amplitude of 10 to 100 microvolt and the frequency of EEG signal lies in the range of 1 to 100Hz. EEG signals are characterized by five frequency sub-bands, defined as; delta (1-4 Hz), theta (4-8 Hz), alpha (8-13 Hz), beta1 (13-18 Hz), beta2 (18-30 Hz) and gamma (>30 Hz). These EEG signal sub bands are associated with the neural activity and tend to change under different circumstances. Thus, accurate extraction and analysis of these features can lead towards the right interpretation of the correlated emotional state for developing an intelligent man machine interface using EEG. Also, there is a huge demand as well as a scope to the make man-machine interface more affective and cognitive by developing algorithmic/software applications/solutions for new generation robotic devices. Artificial intelligence systems
possessing these capabilities can have a huge range of real world applications in areas including control, psychiatry, medical field, lie detection, security services and telecommunications. Recognizing emotions from biomedical signals is an efficient technique to implement man-machine interface systems. It creates a communication channel between the human and computer by acquiring, analyzing and classifying physiological activities under certain stimulations. Automated retrieval of emotional states from physiological signals like EEG is gaining noticeable attention nowadays since affective computing in the context of human neural responses can lead to the development of brain-computer interfaces. The designed BCIs can be further programmed towards the development of a neuro-scientific and medical tool that can progressively contribute to assist medically challenged people suffering from certain psychiatric/depression disorders. Hence, a need is there for the development of an efficient computer-aided method for automatic detection and classification of emotions based on human neural responses.

Further, physiological signals like ECG and EEG are continuously recorded over prolonged time periods at extremely high resolution. Thus possess enormous data size and require more transmission bandwidth for remote analysis. However, successive ECG beats and EEG samples show some redundancy along with the information content. It would be advantageous to compress ECG and EEG signal by removing this redundancy for long distance transmission during telehealth monitoring. Compression of ECG/EEG data shall enable the representation of cardiac/neural signal with comparatively lower number of bits while retaining the important diagnostic information in reconstructed signal.

1.2 MOTIVATION

Cardiac diseases are the third of the leading causes of death worldwide, and India itself is home to 60 per cent of cardiac disease patients. It is thus, posing a serious health threat particularly, in the Indian Asian population. Therefore, computer-aided detection and classification of ECG signal is very useful in healthcare technology, as it can help the physicians to diagnose cardiac disorders accurately at early stages and act faster in case of emergency conditions.
Similarly, Aging population/medically challenged people suffering from Neural/Psychiatric/Depressive disorders face extreme difficulty in communicating with the external world. Thus, development of emotion-specific EEG-based brain-computer interfaces can be a step towards to overcome that limitation by developing a neuro-scientific medical tool to assist such patients to restore or maintain a quality life.

Compression of physiological signals like ECG and EEG may enable cardiologist/neurologist to accurately analyze and detect cardiac/ neurological condition of the patient, respectively, by extracting important diagnostic parameters from reconstructed ECG/EEG signal even at remote locations to aid telemedicine applications.

1.3 PROBLEM STATEMENT FORMULATION

The current progress through the literature has been accessed and is found that computer-assisted automatic analysis and classification of basic human physiological parameters like ECG and EEG with higher accuracy and reduced complexity is the need of the hour. The problem of the proposed research is to analyze physiological signals using a fusion of time domain and frequency domain techniques by overcoming various limitations such as less accuracy due to Fourier phase suppression and high computational complexity faced by conventional signal analysis techniques and eventually exploring the clinical relevance and discriminating ability of higher-order statistics in cardiac state and emotion categorization. In context of physiological signal compression, the aim is towards the development of ECG/EEG signal compression technique that achieves desired reduced information content while retaining the significant diagnostic features.

1.4 OBJECTIVES OF THE RESEARCH

The objectives of the present research shall be:

- To do an extensive literature search on automatic detection and classification of ECG and EEG signals in context of physiology and emotion classification followed by physiological signal compression.
• To develop an ECG beat classification technique to detect different cardiac states using hybrid features (temporal features and higher-order spectral features) of ECG and artificial intelligence tools like neural network classifier.
• To develop an algorithm for the identification of P-QRS-T complexes in ECG signal to establish an appropriate and relevant set of QRS dependent and higher-order spectral dependent features to detect various cardiac disorders from input ECG signal records extracted from the MIT-BIH arrhythmia database of Physiobank ATM.
• To configure and train a classifier by reducing the error rates, training time and thus increasing the cardiac state classification accuracy using MATLAB.
• To further develop an efficient emotion detection and classification technique, based on compact and efficient feature set of EEG.
• To construct emotion specific physiological signal dataset from healthy volunteers in real time by external stimulation, to make them experience the selected emotional state and simultaneously acquiring associated neural responses in terms of EEG using Emotive EEG head set.
• To perform signal analysis and processing of real time acquired EEG using MATLAB based advanced brain mapping toolboxes to interpret associated human emotions to enrich human-computer interface.
• To develop a test program in MATLAB for simulation comparison and implementation of ECG and multichannel EEG compression algorithm based on frequency transformation and parameter extraction techniques.
• To evaluate their effectiveness on the basis of compression ratio, percent root mean square difference and reconstruction parameter accuracy to efficiently store and transmit ECG and EEG signals for remote analysis.

1.5 ORGANIZATION OF THE THESIS

This thesis presents the computer assisted automatic analysis of basic human physiological parameters like ECG and EEG to classify human physiology and emotions.
It is comprised of six chapters with predefined objectives which have been achieved successfully. This thesis is organized as follows:

**Chapter I** comprise brief introduction of the basic concepts of physiological signal processing. It gives an overview of ECG and EEG signal analysis, detection and classification techniques to develop computer-assisted diagnostic tools for early diagnosis of cardiac and neural disorders, respectively. The vital role of automated diagnosis is described in healthcare technology followed by the motivation of the present research. After justification of the research topic and problem statement formulation, objectives of the present research work are defined explicitly. The last section of this chapter gives structure and flow of the thesis which gives brief chapter wise description.

**Chapter II** gives an overview of the extensive literature survey in the area of physiological signal processing as well as its current applications which includes the related and relevant information available in books, journals, transactions and internet websites to understand the current state of international/national research followed by a literature summary highlighting the gaps in literature. A comprehensive survey of existing algorithms is carried out for acquisition, analysis and classification of human physiological signals ECG and EEG in the context of cardiac and emotional state classification, respectively. This section gives the most recent techniques implemented by the researchers for automated cardiac state recognition from human ECG signals followed by the methods used to extract emotions from human neural responses, i.e., EEG. The current progress through the literature has been accessed in order to find the relationship between the unique patterns of ECG/ EEG and correlated cardiac state/emotional state.

**Chapter III** introduces an highly accurate ECG beat classification technique for automated cardiac decision making using time domain and higher-order spectral features of ECG using neural network classifier, while discussing detailed theory behind ECG signal processing, feature extraction as well as the classification methodology used. Accurate non-invasive electrocardiogram analysis has a significant emerging role in automated cardiac state diagnosis. Automated analysis of ECG offers valuable
information for diagnosis and subsequent therapy of cardiac rhythm disorders at early stages. The present research investigated the clinical relevance and discriminating ability of higher-order spectra in the context of cardiac state categorization. A feed-forward neural network classifier is configured as a six states classification system due to their simplicity, robustness and effectiveness in modeling complex relationships between the input and output variables of the system where algorithmic solutions formulation is a cumbersome task.

Chapter IV includes the development of an efficient emotion detection and classification technique using EEG-based affective brain mapping in real time. Psychophysiological analysis of human neural responses via EEG has a significant progressive role in the field of cognitive/affective computing to develop more intuitive and advanced brain-computer interface applications such as human emotion measurement, stress and depressive disorder recognition in real time. Early and accurate diagnosis of depression is crucial as neural/psychiatric/depressive disorders are posing a serious threat and consequently a negative impact on human health. An automated, EEG-based depression diagnostic and management tool is proposed by analyzing multichannel-EEG data using a fusion of time domain (event related potential), frequency domain (power spectral density, amplitude spectral density) and EEG coherence features.

Chapter V includes simulation analysis and implementation of compression schemes for ECG and EEG that can provide feasibility towards implementation of efficient physiological signal storage and especially low-bandwidth medical data transmission systems to aid telemedicine applications. This chapter comprises implementation of ECG and multichannel-EEG compression algorithm based on frequency transformation and parameter extraction techniques. The performance of stated compression scheme is quantified in terms of compression level achieved, and reconstruction error introduced followed by reconstruction parameter accuracy based on parameters extracted from original and recovered dataset.

Chapter VI consists of conclusions of the thesis and the scope for future work. This chapter covers the gist of the research work carried out for the development of more efficient and robust computer assisted diagnostic tools for cardiac state classification via
ECG, and depression diagnosis and management via EEG followed by the physiological signal compression. The concluding remarks of all the preceding chapters are summarized. It also explores the possible extension (future scope) of the proposed methodology.