CHAPTER 1 Introduction

1.1 Background of Research

An electrocardiogram (ECG) is a graphical representation of changes in the difference between electrical potentials at two points on a body surface over time. An ECG signal can provide us with a great deal of information on the normal and pathological physiology of heart activity. Thus, ECG is an important non-invasive clinical tool for the diagnosis of heart diseases. In 1960-61, Pipberger *et. al* [1] developed the first computer program for automatic wave recognition that can be labeled the mother of ECG programs; all programs developed since then have employed the same general principles for wave detection used and documented by Pipberger *et. al*. Around 1965, Nomura's group in Osaka built Japan's first system of computerized ECG processing for operational use in hospitals [2]. At first, they used an earlier type of minicomputer, but later changed to a computerized monitoring system. The success of this computerized ECG processing system has stimulated a remarkable increase of signal analysis techniques on ECG [3-10].

1.2 Problem Statement

A heart disease causes an alteration in rhythm of the heartbeat called arrhythmia. For precise monitoring of arrhythmia, 24-hour ECG using a Holter ECG device is recorded. After the recording, physicians look for abnormal cycles in the ECG recording. However, physicians often overlook abnormal cycles because of mental fatigue, human negligent and misdiagnosis. Therefore, there is a need to build the computerized analytical system that can interpret an ECG accurately. However, the ECG signal changes according to cardiac rhythms, and the waves and complexes constituting the ECG are slightly different for each individual. The waves and complexes vary with changes in the environment surrounding the measurement system for the ECG. Again, there is a need to enhance the adaptive learning capability of the analyzers using signal processing and pattern recognition methodologies.

1.3 Motivation

Presently, many factors seem to give new momentum to research and development in electrocardiography [3-10]. Firstly, the ambulatory monitoring of ECG has established its role in many circumstances, particularly as a detector of rare episodes and for therapeutic control. The increasing availability of low-cost high-performance computing technology also encourages improvement in electrocardiography by offering a reliable and comprehensive solution to the automatic diagnosis of the ECG. Lastly, the rising cost of health care asks basically for a reduction in the circumstances when the admission of patients to hospitals is recommended. A new approach to the design of portable devices for ambulant subjects will help in making the patient less hospital dependent and these equipments should embed and integrate several techniques of data analysis, such as signal processing, pattern detection and recognition, decision support and human computer interaction.

Developments in computerised patient monitoring systems over the recent years have had remarkable demands on automatic ECG analysis systems [3-5]. Whilst researchers have refined and enhanced the way in which automatic detection and classification of cardiac arrhythmia is performed, diagnostic errors can still occur [6-8]. One source of error is often attributed to the variability of the signal characteristics between patients. In addition, the complexity associated with the ECG classifiers prevents the physician from retraining all the neural networks whenever some new ECG signal characteristic is identified. Hence, the online learning algorithm is of paramount importance in preventing the waste of computational cost and time [11, 12].

In this study, a neuro fuzzy classification system is proposed for the automatic analysis of electrocardiogram (ECG). An online learning EKF based neural network system that utilises an ensemble of three individual neural networks is employed. These neural networks are trained separately to distinguish only one different type of ECG abnormalities from that of the normal heart. Then, the recognition of multiple abnormalities is achieved by using a table-lookup based fuzzy logic inference of the combined knowledge acquired by each neural network. By fusing these neural network and fuzzy logic technologies, the system is capable of intuitively analyzing the ECG signal for different types of abnormalities such as Ventricular Premature Cycle (VPC), T wave inversion (TINV), ST segment depression (STDP), and Supraventricular Tachycardia (SVT) and also for the normal heart such as normal sinus rhythm (NSR).

1.4 Objectives of Research

The major objectives of this research are as follows:

1) To develop a novel approach for classifying ECG signals using Extended Kalman Filter (EKF) based neuro fuzzy system.

2) To implement the automatic ECG classification system on computer software.

1.5 Scope of Research

The scope of the thesis includes the followings:

1) The ECG signals are obtained from the MIT-BIH Database [13].

2) To develop an ECG classification system that is able to analyse the ECG signal for three different types of abnormalities (i.e. STDP, TINV, SVT) and also for the normal heart.

3) To implement the online learning EKF algorithm on neural networks.

1.6 Organization of Thesis

In Chapter 1, the background of research is first discussed, followed by the problem statement, motivation, objectives and scope of research for the ECG. In Chapter 2, the literature review of previous works in automated ECG classification is presented. In general, conventional approaches suffer from common drawbacks that depend on high sensitivity to noise and unreliability in dealing with new or ambiguous patterns. An online learning algorithm for the neural network solves this problem by incorporating the additional recognition abilities of such new patterns without having to retrain the whole network. In the first section of Chapter 3, we introduce the important features derived from both morphologic analysis and stochastic information of normal and pathological ECG signals. In Chapter 4, we present various methods for the detection of ECG features. In Chapter 5, we first present the theory of neural network. Then we review the theory of EKF, which is considered as one of the most effective methods for both nonlinear state estimation and parameter estimation. The EKF is adopted as an online learning algorithm for the neural network. In the following section, we describe the use of an ensemble of neural networks for ECG clustering. These neural networks will cluster the various ECG signals into homogeneous groups using a divide and conquer approach. In Chapter 6, we discuss the use of a fuzzy logic based inference system to further classify these homogenous groups into proper classes. Chapter 7 presents the simulation results for the classification of various ECG signals. Finally, we give the overall conclusions and suggest relevant directions for future work in Chapter 8.