Chapter 1
1.1 Need for the Thesis

During the past decade, technological innovations have progressed at such an accelerated pace that they have permeated almost every facet of life. This is especially true in the fields of medicine and health care services. In the current era of modern industrial world, more emphasis is given for the implementation of modern technology and advanced research in the area of health care. Defined as the use of the principles and techniques of engineering to solve problems in biology and medicine, biomedical engineering today holds a prominent place as a means of improving medical diagnosis and treatment. Biomedical engineers are expected to support the physicians by developing more sophisticated techniques to understand the real-time functioning of various organs of the body and hence the diagnosis.

Scope of biomedical engineering is exceptionally wide and ranges from nanomedicine to space medicine, from molecular and cellular engineering to robotics applied in surgery, and from neuromuscular systems to many devices such as mechanical heart pump and artificial lung. Due to the rapid developments that have been taking place in the fields of applied sciences, biomedical research is able to make astounding achievements [1].

Modern computer technology offers immense advantages with respect to the capture, storage, analysis and communication of biomedical signals, but it remains to be
conclusively established how these facilities can routinely and effectively be employed to aid the day-to-day diagnosis and management of patients. Computers and artificial intelligence techniques have created ample scope for research in analysis of physiological signals and subsequent decision making for diagnosis.

Respiratory system, which performs the process of exchange of gases between the body tissues and external environment, is a crucial physiological system in human body. Human respiratory system consists of the lungs, conducting airways, respiratory muscles, and the surrounding tissues and structures. Supply of oxygen to the tissues and excretion of carbon dioxide occur through respiration, and thus it plays an essential role in sustaining life and promoting growth.

Complication of the respiratory system is recognised as a major source of abnormal behaviour of human physiological system. Performance of the respiratory system depends on the integrity of airways, the pulmonary vascular system, the alveolar septa, the respiratory muscles, and the respiratory control mechanism. A complete assessment of the functional status of these systems is essential for the prevention and optimum management of respiratory impairments. Apart from diagnosis, early detection of degradation in performance of respiratory system will also help the physician to initiate therapeutic measures. This will be especially useful for employees working in textile industries, coal mines, and smoke filled environments. Performance of the respiratory system can be assessed by analysing the signals obtained by pulmonary function tests (PFTs). Apart from PFTs, lung sounds are also effectively used for diagnostic purposes. Modelling of the respiratory system under exercise will also help in detecting certain diseases.
1.1.1 Diagnosis of Respiratory System

Pulmonary function tests (PFTs) are used to assess the functional status of the respiratory system and detect any disorders. PFTs are very sensitive and will normally detect abnormalities in lung function well before lung disease has become clinically apparent. Various types of PFTs typically performed in a respiratory therapy laboratory include spirometry, helium dilution, nitrogen washout, body plethysmography, diffusion capacity, pulse oximetry, respiratory gas analysis, and blood gas analysis tests.

Spirometry is the most widely used PFT for diagnosis and management of respiratory system. In spirometry, the flow rate and volume of air inspired and expired are measured as a function of time using an equipment called spirometer. Spirometry provides useful information about overall respiratory system for categorizing and staging pulmonary diseases. In this thesis, novel techniques for using spirometry data for analysis and diagnosis of respiratory system have been proposed. Soft computing techniques such as artificial neural network (ANN) and genetic algorithm (GA) were used in this purpose.

Apart from the PFTs, lung auscultation can also be used for the management and follow-up of respiratory patients. As the pathological changes of the lungs produce characteristic sounds, auscultation gives direct information about the functional status of the lung. Time-frequency analysis of lung sounds was performed applying wavelet transform (WT). Using the wavelet coefficients, lung sounds were classified with the help of ANN.

1.1.2 Respiratory System under Exercise

The study of exercise physiology leads to an excellent understanding of the way the body is supposed to work while performing at its healthy best. During exercise
all physiological responses become a highly integrated, total supportive mechanism for the performance of the physical stress of exercise. Difficulty exists in understanding the complex nature of respiratory control under exercise. Exercise testing allows evaluation of the lungs under conditions of increased metabolic demand, so that abnormalities not readily defined in terms of decreased flows, volumes, or diffusing capacities may be quantified. It also helps the physician in diagnosing certain diseases such as exercise induced asthma and dyspnea. Exercise study of the respiratory system will also be useful for designing exercise devices such as treadmill, bicycle ergometer, etc. This thesis also looks at the variation of breathing rate under exercise from the point of view of optimal control of minimum work rate criterion.

A block diagram depicting the application of techniques described in this thesis for analysis of respiratory system is shown in Fig. 1.1.

1.2 Objectives

The main objectives of the thesis are summarized below.

1. To formulate a novel technique based on ANN for the evaluation of reference values of important lung parameters.

2. To investigate the application of model based indices representing the airway resistance for the diagnosis of chronic obstructive pulmonary diseases (COPDs).

3. To perform time-frequency analysis of lung sound signals using wavelet transform, and diagnostic classification with ANN.

4. To develop a mathematical model describing the variation of breathing rate under various stages of physical exercise.
1.3 Outline of the Thesis

A general discussion on the physiology of human respiratory system and the diagnostic techniques is provided in chapter 2. A novel method of obtaining the spirometric reference values using ANN is described in chapter 3. Chapter 4 describes the development of model based indices for maximum expiratory flow volume (MEFV) curves. Evaluation of the model parameters using GA, and their application in diagnosis using ANN are also described in this chapter. Chapter 5 presents the usefulness of lung sound analysis using time-frequency techniques. A discussion on the wavelet transform and neural classification of lung sounds using wavelet coefficients is given.
in this chapter. Modelling of human respiratory system under exercise is discussed in chapter 6. Equations have been derived for the breathing rate of subjects under various stages of exercise. The observations and conclusions of this research are summarized in chapter 7. The concluding discussions include recommendations for future investigations.