Department of Telecommunication Engineering
Hijjawi Faculty for Engineering Technology
Yarmouk University

Wireless Remote Monitoring System for ASTHMA Attack Detection and Classification

Prepared by
Orobh Mohammad Ali Al-Momani

Supervised by
Dr. Khaled Gharaibeh

April 2013
Wireless Remote Monitoring System for ASTHMA Attack Detection and Classification

By
Orohh Mohammad Ali Al-Momani

Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science in Electrical Engineering

At
Hijjawi Faculty for Engineering Technology
Yarmouk University

April, 2013

Committee Members

Dr. Khaled Gharabeh (Chairman)

Dr. Mahmood Al-Khassaweneh (Member)

Dr. Mohammed S. Aboqlah (Member)

Signature and Date
Acknowledgments

I would like to extend my thanks to my supervisor Dr. Khaled Gharaibeh who guided and encouraged me throughout all my research.

I would also like to Thank Dr. Nedal Shawagfeh and Dr. Alaa Ayasra from King Abdullah University Hospital for their help in providing medical information and data.

I would also like to show my gratitude to my family for their love and support.

\[ ^1 \text{This work was supported in part by the Scientific Research Fund (SRF), Ministry of Higher Education and Scientific Research, Jordan under grant number (H/1/05/2011).} \]
Table of Contents

Chapter 1 ......................................................................................................................................... 1
  Introduction ..................................................................................................................................... 1
    1.1 Remote Monitoring of ASTHMA Attacks ....................................................................... 2
    1.2 Problem Statement ......................................................................................................... 4
Chapter 2 ......................................................................................................................................... 7
  Literature Review............................................................................................................................ 7
    2.1 Effect of Wireless Channels on Transmission of Medical Data ...................................... 7
    2.2 Classification of Body Signals Related to ASTHMA ...................................................... 8
    2.3 Conclusion ...................................................................................................................... 10
Classification and Data Fusion of Medical Signals ...................................................................... 11
  3.1 Feature Extraction of Medical Signal............................................................................. 11
    3.1.1 Feature Extraction using Mel-Frequency Cepstral Coefficients (MFCC) .............. 12
    3.1.2 Feature Extraction using Wavelet Transform ......................................................... 14
  3.2 Classification of Medical Signals ................................................................................... 16
    3.2.1 Support Vector Machines ....................................................................................... 16
    3.2.2 Hidden Markov Models .......................................................................................... 23
  3.3 Data Fusion ................................................................................................................ ...... 25
    3.3.1 Bayesian Data Fusion ............................................................................................. 27
    3.3.2 Fuzzy Logic ............................................................................................................ 28
  3.4 Conclusion ................................................................................................................ ...... 32
Chapter 4 ....................................................................................................................................... 33
  Fading in Wireless Health Monitoring Systems ........................................................................... 33
    4.1 Models of Fading Channel ............................................................................................. 34
    4.2 Types of Fading............................................................................................................... 36
    4.3 Effect of Fading on Medical Signal ............................................................................... 38
    4.4 Conclusion................................................................................................................ ...... 39
Chapter 5 ....................................................................................................................................... 41
  The Proposed ASHTMA Attack Detection System................................................................. 41
    5.1 System Design ................................................................................................................ 41
5.2 Feature Extraction of Cough Signals ................................................................. 43
5.3 Classification of Cough Signals ...................................................................... 45
5.4 Data Fusion of Body Signs ............................................................................. 48
5.5 System Performance with Wireless Channels ............................................... 51

Chapter 6 .............................................................................................................. 54
Simulation Result .................................................................................................. 54
6.1 Data Collection .............................................................................................. 54
6.2 Simulation Model for SVM Classification of Cough Signals ......................... 55
6.3 Simulation of Data Fusion ............................................................................ 56
6.4 Simulation Results ......................................................................................... 58
   6.4.1 Classification of cough signals without Channel Impairment ................ 58
   6.4.2 Classification of cough signal In AWGN Channel ................................. 59
   6.4.3 Classification of cough signal in Rayleigh Fading Channel .................... 60
   6.4.4 Data Fusion Results without Channel Impairments ............................. 62
   6.4.5 Data Fusion in AWGN Channel ............................................................. 62
   6.4.6 Data Fusion in Rayleigh fading channel: .............................................. 63
   6.4.7 Diagnosis of ASTHMA attack: .............................................................. 65

Chapter 7 .............................................................................................................. 68
Conclusion and future work .................................................................................. 68
   Original Contributions: .................................................................................... 69
References: ........................................................................................................... 70
List of Figure:

Figure 1: The proposed ASTHMA attack wireless monitoring system ........................................ 5
Figure 2: Block diagram of MFCC ............................................................................................ 13
Figure 3: Block diagram of Wavelet transform ......................................................................... 14
Figure 4: (a) a cough signal and (b): its Wavelet transforms .................................................... 16
Figure 5: Hyper-plane through two linearly separable classes [27] ......................................... 17
Figure 6: Soft margin classifier [35] ........................................................................................ 20
Figure 7: Nonlinear data map to higher dimensions [37] ............................................................ 22
Figure 8: A left-right HMM with three states: $\lambda = (\pi, A, B)$ initial state distribution ($\pi$), state transition probabilities (A) and observation probability distribution (B) [40]. ....................... 25
Figure 9: JDL Data Fusion model [41] ..................................................................................... 26
Figure 10: Element of Fuzzy system .......................................................................................... 29
Figure 11: Multipath effects in wireless channels [54]. ............................................................... 35
Figure 12: The proposed wireless remote monitoring system of ASTHMA attacks ................. 42
Figure 13: Block diagram of MFCC .......................................................................................... 43
Figure 14: (a) A cough signal of ASTHMA patient and (b); its MFCC features ....................... 44
Figure 15: Tree SVM classifier system ...................................................................................... 45
Figure 16: SVM Classifier model ............................................................................................... 46
Figure 17: Block diagram of fuzzy logic ..................................................................................... 49
Figure 18: Membership function (a) HR (b) RR (c) SPO$_2$ (d) output ........................................ 50
Figure 19: Block diagram of Channel Models ............................................................................ 52
Figure 20: Block diagram of simulation procedure ................................................................. 55
Figure 21: Block diagram of SVM training process ................................................................. 56
Figure 22: Block diagram of the data fusion scheme used for detection of Asthma attacks .......... 57
Figure 23: Correct Classification rate vs. SNR in dB of cough signal .................................... 59
Figure 24: BER vs. SNR in dB of cough signal ..................................................................... 60
Figure 25: Correct Classification rate in Rayleigh channel of cough vs. SNR in dB at different Doppler shift ................................................................. 61
Figure 26: BER in Rayleigh channel of cough signal vs. SNR in dB at different Doppler shift 61
Figure 27: Correct Classification rate vs. SNR in dB at data fusion ..................................... 62
Figure 28: BER of fused data vs. SNR in dB at data fusion .................................................. 63
Figure 29: Correct Classification Rate vs. SNR in dB at data fusion with Doppler shift ........ 64
Figure 30: BER of fused data vs. SNR in dB at different Doppler shift ................................. 65
Figure 31: Rule based method for ASTHMA attack .............................................................. 66
Figure 32: Fuzzified method of an ASTHMA attack ............................................................ 67
List of tables:

Table 1: Kernel functions [35] ......................................................................................................................... 22
Table 2: Noise performance of ECG signal transmission for urban channel profile with mobility .......................................................... 39
Table 3: Noise performance of ECG signal transmission for rural area cellular channel profile 39
Table 4: MFCC parameters ............................................................................................................................ 44
Table 5: Membership function values for patients whose age is above 5 years ........................................... 57
Table 6: Membership function values for patients whose age is less than 5 years ....................................... 58
Table 7: Confusion matrix ............................................................................................................................... 58
Table 8: Result of classification of cough signal at different Doppler shift .................................................. 61
Table 9: Result of classification of data fusion at different Doppler shift ..................................................... 64
Abstract

ASTHMA attacks may cause sudden death; therefore, detecting ASTHMA attacks using continuous remote health monitoring systems could contribute to saving lives of ASTHMA patients. ASTHMA attacks occur when the ASTHMA patient is in a polluted environment and is usually accompanied by increased cough rates and duration; increased heart beat acceleration, increased respiration rate and decreased saturated oxygen. Continuous remote monitoring of these signals can be done using wireless technology which is available to most patients through the cell phone network. Cough sounds and other body vital signs related to ASTHMA attacks can be transmitted in real time to a remote unit located at a hospital where signal detection and classification can be conducted in order to detect an ASTHMA attack. Doctor intervention can then be done by calling the patient to take precautions, take a certain medication or to go to a health care center for proper treatment.

This thesis aims at developing a model for wireless remote monitoring system where body signal related to ASTHMA are transmitted to a remote hospital in real time. Detection and classification algorithm operate on real time data to make a decision about the existence of ASTHMA attacks. There are two main components of the proposed system: first, a classification algorithm is developed to detect and classify body signals and to make a decision on the existence of ASTHMA attacks. Second, the effect of wireless channels on decision making is studied in order to decide on the best wireless technology to be used in such scenario.
Chapter 1

Introduction

ASTHMA is a chronic lung disease that cannot be cured but can be controlled by taking medicine and making changes in the environment. People with ASTHMA have very sensitive airways that react, for example, to cigarette smoke, allergies, infections, or cold air. ASTHMA episodes may come and go, but the lungs stay sensitive to the things that trigger ASTHMA. Poor control of ASTHMA may lead to frequent emergency room visits or hospital stays and can also cause death [1] [2].

ASTHMA signs and symptoms vary from person to person, and may get worse or better over time. The main symptoms of ASTHMA are coughing, shortness of breath, wheezing, inability to sleep at night, inability to exercise, etc. Doctors may order some tests to know if a patient suffers from ASTHMA such as breathing tests, chest X-ray, and tests to show whether breathing problems may be caused by allergies or heart disease [2].

Clinical diagnostic and treatment of Asthmatic patients require the measurement of several biological parameters such as heart rate(HR), respiration rate(RR), cough and saturation of oxygen (SPO2 )[3]. Measurement of these parameters is usually performed by medical sensors which are capable of perceiving body signs and mapping of these signs to a quantitative measurement in a consistent and predictable manner [3].

An ASTHMA attack is a sudden worsening of ASTHMA symptoms caused by an exposure to allergens or irritants such as inhaling dry and cold air and certain allergens such as pets, pollens, dust, and smoke. The symptoms of ASTHMA attack may vary in severity and duration from person to person; early warning signs of ASTHMA attack are headache, chronic
cough, and blue color in skin, difficulty in talking and difficulty in breathing. When these early signs of ASTHMA attack are noticed, one should immediately seek medical treatment in order to prevent severe ASTHMA attacks [4][5].

The symptoms of severe ASTHMA attack develop gradually and may become serious within 6-48 hours. There are certain signs that indicate worsening severity of ASTHMA attack. These signs include an increased heart rate, an increased respiration rate, decrease saturated oxygen and increased cough rates and duration [5][6]. Therefore, detection of an ASTHMA attack and quick medical intervention requires monitoring and processing of these signs in patient in real time where decision can be made about the occurrence of an ASTHMA attack. Making decision about the occurrence of an ASTHMA attack requires classification of cough signals and data fusion of various body signs related to ASTHMA.

1.1 Remote Monitoring of ASTHMA Attacks

The application of wireless telemedicine is seen as a useful and potentially powerful tool to improve the quality of health care especially for patients with chronic diseases. With remote monitoring, the medical staff can realize changes in the parameters of patients without frequently visiting them and consequently they can take precautions to prevent possible aggravations. It has also helped patients to live more safely and longer in their location of choice [7].

Remote monitoring has recently emerged to provide real-time patient surveillance and chronic disease patients with more autonomy, such as in patients with chronic heart failure by monitoring of vital signs (HR, SPO2, and Blood Pressure) performed at patients’ home. Remote monitoring of body vital signs is identified by physicians and administrators as an important strategy to early detection and treatment to the alterations in vital signs that precede the acute
syndromes. These systems are designed to reduce the number of consequent hospitalizations and related costs [8] [9].

Remote patient monitoring system technologies follow a general architecture that consists of [3] [10]:

1. Sensors on a device that is enabled by wireless communications to measure physiological parameters such as heart rate (HR), respiration rate (RR), saturation of oxygen (SPO2).
2. Local data storage at patients’ site that interfaces between sensors and other centralized healthcare providers.
3. Diagnostic application software that develops treatment recommendations and intervention alerts based on the analysis of collected data.

For patients with ASTHMA, continuous monitoring of body signals is needed in order to detect ASTHMA attacks and try to save their lives by taking proper medical intervention measures [7][8][9]. Continuous remote monitoring of body signals related to ASTHMA such as cough, heart rate, respiration rate, SPO2 can be done using wireless technology which is available to most patients through cell phone networks. These signals can be transmitted in real time to a remote unit located at a hospital where signal detection and classification can be conducted in order to detect ASTHMA attacks. Then, a doctor intervention can be done by calling the patient to take precautions, ask him/her go to a health care center for proper treatment or take a certain medication [3].

In general, a wireless monitoring system for ASTHMA patients must consist of two main components: the first is a wireless sensor system that has the ability to measure and transmit