DEVELOPMENT OF A WIRELESS REAL-TIME REMOTE CONTROL AND TELE-MONITORING SYSTEM FOR THE MECHANICAL VENTILATOR

By

Heba Sedik Farghaly Rostom

A Thesis Submitted to the
Faculty of Engineering at Cairo University
in Partial Fulfillment of the
Requirements for the Degree of
MASTER OF SCIENCE
in
Biomedical Engineering and Systems

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
GIZA, EGYPT
2016

DEVELOPMENT OF A WIRELESS REAL-TIME REMOTE CONTROL AND TELE-MONITORING SYSTEM FOR THE MECHANICAL VENTILATOR

By

Heba Sedik Farghaly Rostom

A Thesis Submitted to the
Faculty of Engineering at Cairo University
in Partial Fulfillment of the
Requirements for the Degree of
MASTER OF SCIENCE
in
Biomedical Engineering and Systems

Under the Supervision of

Prof. Ayman M. Eldeib

.....

Professor of Biomedical Engineering and Systems
Biomedical engineering and systems
Faculty of Engineering, Cairo University

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
GIZA, EGYPT
2016

DEVELOPMENT OFAWIRELESS REAL-TIME REMOTE CONTROL AND TELE-MONITORING SYSTEM FOR THE MECHANICAL VENTILATOR

By
Heba Sedik Farghaly Rostom

A Thesis Submitted to the
Faculty of Engineering at Cairo University
in Partial Fulfillment of the
Requirements for the Degree of
MASTER OF SCIENCE
in
Biomedical Engineering and Systems

Approved by the
Examining Committee

_____
Prof. Dr. Ayman M. Eldeib, Thesis Main Advisor

_____
Assoc. Prof. Dr. Ahmed H. kandil, Internal Examiner

_____
Prof. Dr. Ahmed F. Seddik, External Examiner
(Professor of Biomedical Engineering, Helwan University)

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
GIZA, EGYPT
2016

Engineer's Name: Heba Sedik Farghaly Rostom
Date of Birth: 15./7/1983
Nationality: Egyptian
E-mail: Heba_helwan5@yahoo.com……
Phone: 01022105574
Address: AL Moqatam – Cairo Governorat

Registration Date: 1./10./2010
Awarding Date: 2016
Degree: Master of Science
Department: Biomedical Engineering and Systems

Supervisors:

Prof. Ayman M. Eldeib

Examiners:

Prof. Ayman M. Eldeib (Thesis main advisor)
Assoc. Prof. Ahmed H. Kandil (Internal examiner)
Prof. Ahmed F. Seddik (External examiner)
(Professor of Biomedical Engineering, Helwan University)

Title of Thesis:

Development of a wireless real-time remote control and tele-monitoring system for the mechanical ventilator.

Key Words:
Mechanical Ventilator; Telemedicine; Arduino; Respiratory failure diseases, Tele-monitoring patient.

Summary:

There are many reasons that lead to increase the mortality of the respiratory failure patients, who are undergoing the hospital mechanical ventilator. From these reasons, the inability of an expert doctor to follow up such patients where he/she cannot stay with them all time. In addition to, in most cases especially in public hospitals, lack of the experience of some physicians lead to the inability to provide the necessary therapeutic service at the suitable time for such patients. In this work, we provide a new approach for tele-controlling and tele-monitoring the mechanical ventilator while tele-monitoring a patient when is demanded. In this approach, we use a simple and a lightweight unit placed inside the device in an easy and a safe way. Our system has four sections: the Arduino kits, the interface board, IP camera, and the html web control page. Our system provides live videos for a patient and the device when is needed, then, a doctor can follow up his/her patient and control the device when he/she wants. In addition to, this system can tele-control the device from anywhere without causing any defect to the internal circuitry of the device. This system can be applied to several medical devices not only the hospital mechanical ventilator, in addition to, provides a wireless real-time remote control for the device without any considerable delay.

Acknowledgments

I would like to thank my God who gives me the power and patience to complete this thesis.

My sincere thanks to Prof. Dr. Ayman who support me, and his constructive comments and suggestions improved the quality of this thesis.

I would like to thank my husband and my daughters who gave me support and encouragement to complete thesis. Special thanks for my mother, my sister, all my friends, Eng. Mohamed Magdy, and for Eng. Ahmed A. El-Bary who help me a lot.

Dedication

To

Egypt

Table of Contents

List of Tables

List of Figures

Nomenclature

A\C mode	Assist/Control mode
A\D	Analog to Digital
C2DM	Android cloud to Device Messaging
CPAP mode	Continuous Positive Airway Pressure
CT	Computed Tomography
ECG	Electrocardiogram
Fio2	Fraction of inspired oxygen
GPRS	General Packet Radio Service
GSM	Global System for Mobile
GUI	Graphical User Interface
ICU	Intensive Care Unit
MRI	Magnetic Resonance Imaging
MV	Minute ventilation
PDA	Personal Digital Assistant
PEEP mode	Positive End-Expiratory Pressure
SIMV mode	Synchronous Intermittent Mandatory Ventilation mode
TCP	Transmission Control Protocol
VFD	Variable Frequency Drive
WEP	Wired Equivalent Privacy
WPA	Wi-Fi Protected Access
WPA2	Wi-Fi Protected Access II

Abstract

There are many reasons that lead to increase the mortality of the respiratory failure patients, who are undergoing the hospital mechanical ventilator. From these reasons, the inability of an expert doctor to follow up such patients where he/she cannot stay with them all time. In addition to, in most cases especially in public hospitals, lack of the experience of some physicians leads to the inability to provide the necessary therapeutic service at a suitable time for such patients. The aim of this work is to develop a new approach for a wireless real-time tele-monitoring and tele-controlling system for the hospital mechanical ventilator; it also allows tele-monitoring the patient. In this work, we built a simple, a lightweight, a low cost, and a small unit (12.5x5.5x3 cm) depending on the truth table of the output of a keypad and a knob of the device. Therefore, we don't need to go deep in the keypad construction and the processor software to construct the proposed system. Our system has main four sections: the Arduino kits, the interface board, IP camera, and the html web control page. Our system provides live videos for a patient and the device when is demanded. In addition to, it can tele-control the device from anywhere without causing any defect to the internal circuitry of the device. Hence, using any mobile or a computer connected to the internet, a distant physician can control the device and observe his/her patient all the time to provide a quick and a proper care for him/her at a suitable time. In addition to, the proposed system can be applied to most of the medical devices not only the hospital mechanical ventilator, and provides a wireless real-time remote control for the device without any considerable delay.

To evaluate this system, we applied it to three types of the mechanical ventilators with three different types of keypads. To apply this module, we just need to place it inside the device and connect it to the connector board of the ventilator in a simple and a safe way. We could use the web control page to control the device just after entered the IP address and the password of the page, which increases the privacy for this system. It was easy and familiar for the operator to deal with the web control page, which has the same shape of the ventilator keypad. In addition to, the operator could observe the patient and the device clearly and realistically. Hence, the presented module revealed good results for tele-monitoring the patient and tele-controlling the hospital mechanical ventilator in the real-time.

Chapter 1 : Introduction

This thesis is intended to present a new approach to wireless control the mechanical ventilator and any medical devices have keypads similar to the keypads of the used devices in this thesis or have any types of the keypads. In addition to, the presented system in this thesis allows tele-monitoring for a patient. Hence, a distant physician can follow-up his/her patient to provide a quick and a proper care for him/her from any place.

This chapter presents the motivation behind this thesis and the definition of the main problem, which we will solve in this thesis. In addition to, it displays the scope and objectives of this thesis, finally, the organization of the thesis.

1.1. Motivation

Many of the deaths of patients with respiratory failure are due to lack of the experience of some physician to deal with such patients, or to adjust the mechanical ventilator device at the suitable settings for such patients. In addition to, the inability of a distant professional physician to follow-up such patients all the time lead to the inability to provide the necessary therapeutic services for them. Hence, there is increasing in the mortality of such patients, who suffer from this disease. Then, the patients suffer from respiratory failure need to a professional physician to follow-up them all the time and provide the proper care for them. In addition to, these patients need to an expert physician for adjusting the mechanical ventilator at a suitable setting for them.

The appropriate solution is to find a safe way to follow-up these patients continually and tele-control the setting of the mechanical ventilator in a real-time. In addition to, this solution should be not complicated, inexpensive, connected to the most commercially mechanical ventilators, and safe for the devices and the patients.

Therefore, using the concept of telemedicine is a suitable and a safe way to solve this problem. Based on the concept of telemedicine, several studies were proposed for the mechanical ventilator. Most of these studies only allow monitoring of the ventilation signals, applied only on a home mechanical ventilator, and sometimes don't transfer data in a real-time.

Therefore, this thesis aims to tele-control the hospital mechanical ventilator, which has a complex structure and settings. In addition to, the proposed telemedicine module in this thesis can control any medical devices even have keypads similar to the keypads of the used devices in this thesis or have any types of the keypads.

Applying this application will allow a distant physician to control the setting of a ventilator, and monitor the patient through a mobile or any computer connected to the internet. In addition to, this application allows tele-monitoring the device to ensure that only the desired setting has been done and the settings are suitable for the patient. To

apply this system on the mechanical ventilator, we need only to attach the proposed module cables to the connector (interface) board of the ventilator. In addition to, plug the keypad and the knob cables of the mechanical ventilator on the Arduino board of the module. Then, log in the web control page by entering its IP address and the password to start the medical device control.

The web control page is designed to be similar to the shape of a keypad of the ventilator to be familiar to the physician, not need for training, and easy to use. Hence, it is easy for the physician to deal with this web control page, which can be adapted as the keypad of the mechanical ventilator. In addition to, we used IP camera to view the live videos from anywhere for the patient and the device continually. Therefore, a distant physician can follow-up the patient, adjusts the device at a suitable setting for the patient, and ensures that the required changes in the setting have been done in the real-time. In addition to, this camera can display any messages or alarms appear on the screen of the mechanical ventilator in the real-time to allow a physician to provide a quick and a proper care for the patient.

1.2. Problem definition

The main problem that is reported in this thesis is about the construction of a simple and a low-cost telemedicine system. On the other hand, this system should be not complicated, easy to use, and allowing tele-controlling the hospital mechanical ventilator in a safe way to:

1. Modify the settings of the mechanical ventilator wirelessly.
2. Monitor the changing in the setting of a ventilator.
3. Display any alarms or messages appear on the monitor of a ventilator.
4. Allow tele-monitoring for a patient continually.
5. Do all the previous actions in the real time, and be sure that is safe for a patient and the device. In addition to, the proposed module can be connected to any medical devices.

1.3. Scope and objectives

The scope of this thesis is to design an easy and a cheap telemedicine system that is allowing tele-controlling the hospital ventilator. In this thesis, the focus is to use this system not only for one kind of the ventilators but also can be used with the other medical ventilators. In addition to, this system is designed to be compatible with any medical devices as the infant incubator, the infant warmer, the syringe pump, and etc.

The overall objectives are to allow doctors to tele-control and tele-monitor the mechanical ventilator through any mobile or any computer connected to the internet. In addition to, ensure that the patient receives appropriate treatment, and this system can be connected to the most mechanical ventilators. On the other hand, the wireless control system is designed to do all actions in the real-time to provide a suitable service at a suitable time for a patient. Therefore, the readjustment of the settings of the mechanical ventilator, and tele-monitoring the ventilator and the patient will be in the real-time.

1.4. Organization of the thesis

The remainder of this thesis will be organized as follows:

Chapter 2 provides an introduction about the telemedicine and the ventilator, and a detailed survey of the previous studies.

Chapter 3 presents the materials used to construct the proposed telemedicine module, and the used medical devices for testing the module. In addition to, it presents the methodology of applying the proposed module on the mechanical ventilators.

Chapters 4 shows the results of applying the proposed module on three types of the ventilators, discusses the results, and presents the advantages and the disadvantages of the presented work in this thesis. In addition to, in this chapter we compare between the presented system in this thesis and the previous systems.

Chapter 5 presents the conclusion, and displays the future work for improving the presented telemedicine module to enhance the results of applying this module on the medical devices.