A portable artificial respirator with remote managing features

Abdelouahed Selmani¹, Bachir Benhala², Abi Soufiane³, El Hajjami Imaed³, Mohamed Guerbaoui³, Abdelali Ed-Dahhak³, Abdeslam Lachhab³.

¹ S.A.R.S Team, ENSA of Safi, UCA University, Marrakech, Morocco
² Faculty of Sciences Dhar El Mahraz Fez, Sidi Mohamed Ben Abdellah University, Fez, Morocco
³ EST Meknes, University of Moulay Ismail, Morocco

Abstract. COVID-19 is a disease that particularly attacks the respiratory system. As the situation worsens, the lungs function less effectively, requiring artificial respiration support to maintain adequate oxygen levels. Moreover, the remote supervision of the patient's conditions and remote control of the parameters of a portable breathing apparatus should help decongest hospitals. Such a concept will help healthcare professionals save considerable time by avoiding round trips among patients who do not represent acute respiratory failure. In this work, we describe the basic concepts of telemonitoring of remote patients during ventilation. Our goal is to guarantee the appropriate functioning of a portable respirator including management functionalities. Thus, medical staff can remotely supervise and configure the various components of the portable respiratory system according to the patient's condition.

1 Introduction

Digital health was an undoubted option to respect healthcare guidelines and to encourage people to stay at home or to practice social distancing during the Coronavirus disease (COVID-19). This emergent and rapidly evolving field [1], [2], is based on three essential ingredients namely, the Internet of Things (IoT) [3]–[7], embedded sensors [8], and technologies such as artificial intelligence (AI) [9].

According to statistics, the majority of COVID-19 Patients who develop mild pneumonia do not require hospitalization. They only need respiratory support, hence the need for home use of portable artificial respirators [10]. Thanks to emerging technologies, medical staff can monitor their patient's conditions and also control the breathing apparatus remotely [11]–[14].

The COVID-19 pandemic has created an unprecedented need for remote patient monitoring to contribute to the decongestion of hospitals. Certainly, remote monitoring of mechanical ventilation makes it possible to collect the respiratory vital parameters, thus allowing an accurate interpretation of the various components of the respiratory system to guide the ventilator settings while respecting the required distance to contribute to limiting the propagation of the epidemic Covid-19 [15], [16].
In this optic, this ongoing study aims to develop an innovative telehealth solution able to connect and integrate patients, medical staff, body-worn sensors, and artificial respirators through the internet. Thus, it will allow medical doctors to make adequate decisions about remote actions to support remote patients in hospitals, at home, during transportation, and in rural areas.

This paper is introduced as follows. Section 2 gives the proposed design of the system. Section 3 explains the principle of the main node performing measurement and control tasks. Section 4 presents and examines the control center unit. Section 5 highlights several pieces of information considered in remote monitoring and supervision. Section 6 gives the conclusion and some perspectives on future works.

2 System design

The proposed architecture opted for the ventilator system is given in Fig.1. Several sensors are deployed to collect data from remote patients and to direct it to the remote control center using a local gateway. Gathered data are manually the machinal respiratory status, patient’s respiratory parameters, and the instant temperatures of a patient. Doctors can examine collected data using any terminal. After that, they can immediately send the case report back to the patient or medicals to take adequate setting of the medical instruments.

The Power unit is proposed to power the system even when transporting patients to a hospital or in remote areas. The unit is composed of a hybrid charger able to explore the main power source or solar energy to charge a rechargeable battery.

Fig. 1. System design.

3 Measurement and control unit
In terms of design, the main node is conceived to guarantee real-time remote supervision and monitoring during machinal ventilation. This node is conceived to present meaningful data that can be supervised by remote medical staff. A good interpretation of this data is useful to describe the status of the different constituents of the respiratory system. Data already collected are regularly recorded on a local database for backup and then sent to an online database for constant monitoring. Also, it can activate the alarm in case of critical situations.

This system is expected to reduce significantly the number of critical situations due to probable human errors thanks to its ability to throw early alarms and warnings. It is also a sink that links the respirator to the cloud so that medical teams can check the status of the remote patient. Thus, it can ensure patient safety by assisting remotely on-site medical teams or directly connecting patients so that they can take adequate anticipatory actions in the face of critical situations.

The implementation of the proposed system exploits some software to drive diverse interconnected hardware. The Raspberry Pi 3 board hosts the developed embedded system. The choice is justified by the need to achieve complex calculations and reduce data transmission time since this small card comes with appropriate onboard computing capabilities. The software part is implemented to supervise easily other electronic components and is implemented using Java 8 language as an advanced programming language.

4 Control center

The proposed system can help in keeping the real-time record of every patient in the database on the control center. The records can be checked at a later date if required. The supervisory level which is hosted in the control center uses some machine learning algorithms to achieve an advanced data analysis on collected data. This will boost the elaboration of precise models for patients by performing advanced data mining and further analysis of the gathered data from different patients. These models are used for predicting the respiration status of patients and their response to treatments. Also, the control center can manage data exchange between the main node and medical staff via a web server deployed using the Service Oriented Architecture (SOA) concept where each REST web service is designed to perform special cloud-computing tasks.

5 Remote monitoring and supervision

Medical staff can remotely monitor and supervise real-time patient status using dedicated mobile or desktop applications as shown in Fig.2. As we can see, the front end of the application contains dashboards that present the main useful information and highlight statistical information from connected patients. Patients’ body temperature and other parameters of the respiratory mechanic are collected and reported in real-time thanks to the developed user-friendly GUI. The former helps also to perform remote regulation of the operational settings of the ventilator as follows:

- Showing patient temperature, respiratory rate, environmental temperature and moisture, energy level, and available oxygen, by measuring oxygen saturation (SPO2).
- Ensuring constant monitoring along with data analysis of the conditions of connected patients by viewing the history of the collected information concerning sensor data and the actions of mechanical respirators.
- Tracking all parameters of the artificial respiratory.
• Activating and deactivating the respirator to meet the respiration rates of the patient.

![Screenshot of user software.](image)

Fig. 2. Screenshot of user software.

• Ensure consistent and adequate ventilator operation by updating the patient's respiratory rate and body temperature thresholds.
• Throwing alarms and warnings, namely extreme patient body temperature and system failure, including the connection to the remote server, measurement node issues, and energy insufficiency.
• Initiation of alarms and warnings due to system failure or extreme patient body temperature.

6 Conclusion and future works

This presented work aims to contribute to the extensive efforts to provide the necessary equipment to help health systems combat diseases associated with the respiratory system. The medical staff will use such telehealth solutions to monitor and consult the evolution of their patients remotely and in real-time in isolation centers or at home. Therefore, patients or caregivers are assisted by remote physicians to take necessary measurements. In this way, they will undoubtedly save lives, especially in remote and isolated regions.
Acknowledgments

This article is supported by the National Center for Scientific and Technical Research (CNRST) in Rabat, Morocco as part of the COVID-19 projects.

References