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Wireless coughing detection and respiratory monitoring using a wearable DSP based mems sensor

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ABSTRACT

In this project, a real-time low-power wireless respiratory monitoring system with cough detection is proposed to measure the breathing rate and the frequency of coughing. This system uses wearable wireless multimodal patch sensors, designed using low power off the shelf components. These wearable sensors use a low-power measurement unit to measure the respiratory frequency, and a MEMs microphone to perform cough detection. The architecture of the wireless patch-sensor is presented. The acquisition unit, the wireless communication unit and the data processing algorithms are described. The proposed network performance is presented for experimental tests with a freely behaving user.

Keywords: Cough, respiration, IOT, Hospital healthcare, wireless sensor network, wireless body area network

INTRODUCTION

Wireless body sensors are increasingly used by clinicians and researchers, in a wide range of applications such as sports, space engineering and medicine. Monitoring vital signs in real time can dramatically increase diagnosis accuracy and enable automatic curing procedures, e.g. detect and stop epilepsy or narcolepsy seizures. Breathing parameters are critical in oxygen therapy, hospital and ambulatory monitoring, while the assessment of cough severity is essential when dealing with several diseases, such as chronic obstructive pulmonary disease (COPD).

The current observing framework sensor is set close to the screens or PC, which have constraint of patient's bed. In any case, in present day framework we utilized remote organization and remote gadgets which eliminates the limit of patient's bed. To make human existence more agreeable Wireless sensor organizations (WSNs) are an arising innovation in existing research and can possibly change the method of human existence (i.e., make life more agreeable). A remote sensor is the littlest unit of an organization that has interesting highlights, for example, it upholds enormous scope sending, versatility, dependability; and so forth Body sensor network frameworks can help individuals by giving medical services administrations like clinical observing, memory upgrade, clinical information access, and correspondence with the medical services supplier in crisis circumstances through the IOT or GPRS [1]. Likewise, these frameworks give helpful strategies to distantly obtain and screen the physiological signs without the need of interference of the patient's ordinary life, consequently improving life quality. The present frameworks need the sensors to be set bedside screens or PCs, and cutoff the patient to his bed. However, presently, there is no connection between the sensors and the bedside hardware because of the remote gadgets and remote organizations. The cutting edge medical services observing framework not requires the limit to the patient's to his bed. The patient can move around however in a restricted region from the control room or screen in the advanced framework. In this framework we additionally use foundation situated remote organizations, for example, 3G organization or business cell or remote LAN. Be that as it may, for this situation crisis sign may not communicated from patient to doctor on the grounds that the inclusion of foundation

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arranged remote organization changes with area and time.

LITERATURE SURVEY

The recent technological evolution led to innovative and effective solutions for in-home monitoring and treatment of patients with chronical diseases (such as morbid obesity). In this paper, a survey of e-Health and biomedical applications is presented along with a case study using a home health platform based on the K53 Tower system modules. A broad range of technologies for health parameters measurements are offered by this platform that can be used in remote monitoring in patients at risk. This paper proposes a novel solution to in-home monitoring in patients at risk with morbid obesity, focusing on prevention as well as effective intervention in cases of medical emergency proposed at 2021 IEEE.

Albeit normalized in Europe, GSM isn't just an European norm. GSM networks are operational or arranged in very nearly 60 nations in Europe, the Middle East, the Far East, Africa, South America, and Australia. In the start of 1994, there were 1.3 million supporters around the world. By the start of 1995, there were more than 5 million supporters. The abbreviation GSM presently appropriately represents Global System for Mobile correspondences. The designers of GSM picked a problematic (at that point) computerized framework, instead of the then-standard simple cell frameworks like AMPS in the United States and TACS in the United Kingdom.

This was bothersome, on the grounds that not exclusively was the versatile hardware restricted to activity inside public limits, which in a bound together Europe were progressively insignificant, however there was likewise an exceptionally restricted market for each kind of gear, so economies of scale and the ensuing reserve funds couldn't be figured it out. The Europeans understood this from the get-go, and in 1982 the gathering of European posts and transmits shaped an investigation bunch called the gathering unique versatile (GSM) to examine and build up a container European public land portable framework. The proposed framework needed to meet certain models. Great abstract discourse quality.

Low terminal and administration cost. Supports for worldwide wandering. Backing for scope of new administrations and offices. Phantom productivity and ISDN similarity. In 1989, GSM duty was moved to the European Telecommunication Standards Institute (ETSI), and stage I of the GSM details were distributed in 1990. Business administration was begun in mid-1991, and by 1993 there were a day and a half organizations in 22 nations, with 25 extra nations having effectively chosen or thinking about GSM.

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EXISTING WORK

In literature, several cough monitors have been proposed [6]. The first one has been developed in 1950 with simple audio recording systems that enable to spot manually cough events. In the other hand, some semi or fully automated cough recorders have been designed. In 2006, the Hull Automated Cough Counter (HACC) [7] was developed. It consists of a single audio signal fed into an artificial neural network for detecting cough events. The number of cough components per event is not computed by the system, but can be manually determined.

The system presents a sensitivity of 80% (ranging from 55% to 100% across the 10 validation patients). The Leicester Cough Monitor (LCM) [8] also relied on audio recordings only. Hidden Markov Models (HMM) are used to pre-segment possible cough events, achieving overall sensitivity and specificity of 91 and 99%, respectively. Another system called ”The Vitalojak” [9] is based on a contact microphone placed on the thorax for a semi-automated detection. A lapel microphone is integrated in the system for manual validation. This system has been validated in a 24- hour ambulatory context on 10 patients [10]. It offers a sensitivity higher than 99% while compressing the amount of data to check manually with 3 possible levels, ranging from 65 to 23 minutes on average. In [11], we proposed an audioonly system based on artificial neural networks which achieved a sensitivity and specificity of about 95% on voluntary cough from 10 healthy subjects in various conditions. We analyzed in an objective way the performance of several sensors for cough detection: ECG, thermistor, chest belt, accelerometer, contact and audio microphones. Our contribution consists on exploiting and improving our previously published [12] results within three main factors:

1. Optimization and acceleration of the process of data acquisition within a new prototype, by exploiting fast access memories. This allowed to store data quickly. Consequently, all data are well saved without audio interruptions and noise.

2. Improvement of cough detection precision by extracting cough events which can be presented with several close and successive coughs.
3. The sensors values are interpreted and visualized with a graphical view where the detected cough extracts are visualized and organized accordingly to their similarity in terms of audio properties such as timbre, cough duration and signal energy.

PROPOSED SYSTEM

The overall structure of the system developed in this study is as shown in Figure 1. The sensor attached to the respirator records the wearer's sound and transmits it to the smartphone app through the communication module. The smartphone app retransmits the sound data received from the IoT respirator to the data server, and the data server inputs the transmitted sound data into the trained AI model to detect cough. If the wearer of the respirator coughs more than a certain number of times for a specified period of time, this should be notified to the manager of the medical staff so that the wearer's health can be managed

We used a non-motorized hooded respirator developed by a start-up company, and the INMP441, an omni directional MEMS microphone developed by Intenseness, was used as a sensor for recording sound. As a communication module, the Bluetooth function of ESP32 developed by Expressive Systems was used. Figure 2 shows the respirator and IoT devices used in the development. Since the INMP441 and ESP32 devices operate at low power, they can operate for a long time with a small capacity battery. The ESP32 control program was developed using the Arduino IDE. This control program records sound from INMP441, packetizes the recorded sound data, and transmits it to a smartphone app linked with Bluetooth. In the smartphone app, the transmitted sound data is accumulated for a certain period of time and then retransmitted to the data server.

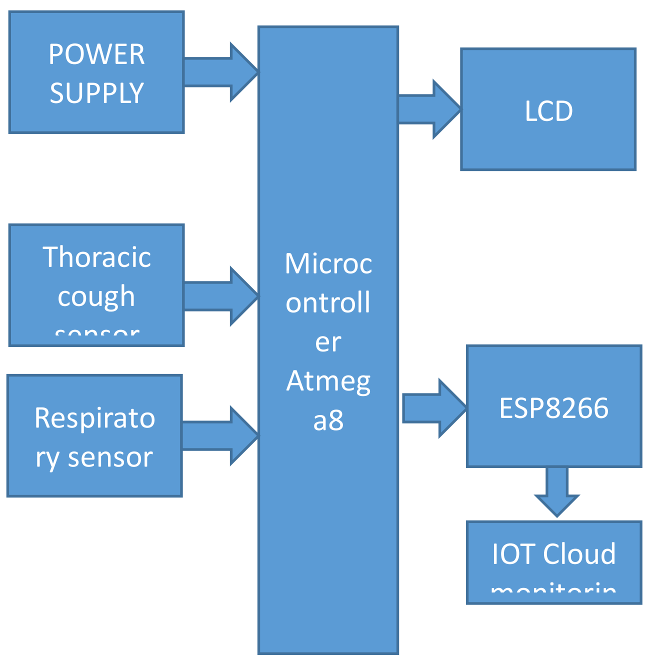

Fig 1

DESIGN OF PATIENT BODY SENSOR NETWORK SYSTEM

In order to detect cough in a continuous audio stream, first, sound data must be separated into frames of a certain size. As shown in the waveform of the cough sound in Figure 3, in the case of coughing, a strong sound occurs from the beginning, and the duration of the cough sound is in most cases within 0.3 seconds. Therefore, our programs analyze the sound frame in units of 10msec, and if a frame with the loudness exceeding a certain threshold is found, the 300msec sound section starting from the frame is cut and saved as a wav-format file continuously as well as displaying data at transmitter side so that patient also observed the relevant outputs and then at the receiver side or in doctors cabin the data is collected with Wi-Fi and microcontroller and displayed on relevant displays. The device can be used outdoors. The Atmega8 is a 16-

bit microcontroller that has a number of special features not commonly available with other microcontrollers: - Complete system on-a-chip — includes LCD control, ADC, I/O ports, ROM, RAM, basic timer, watchdog timer, UART, etc.

HARDWARE

- Power supply unit
- Microcontroller ATMEGA8
- LCD display – 16x2
- Respiration sensor
- Cough sensor
- Wi-Fi ESP8266

SOFTWARE REQUIREMENTS

- Platform - AVR STUDIO
- In System Programmer - ProgISP 172
- Compiler – Win AVR

All sound data were recorded by the sensor of the IoT respirator, and there were 256 cough sounds and 387 non-cough sounds. 85% of this data was used for training AI models, and 15% was used as a test set. Up to 300 epochs were trained, and the change in loss value according to epoch progress during training is shown in Figure 6. The smallest loss value was shown at the 32nd epoch, where the loss value of the test set was 0.00878 (0.88%) and the accuracy value was 0.9794 (98%).

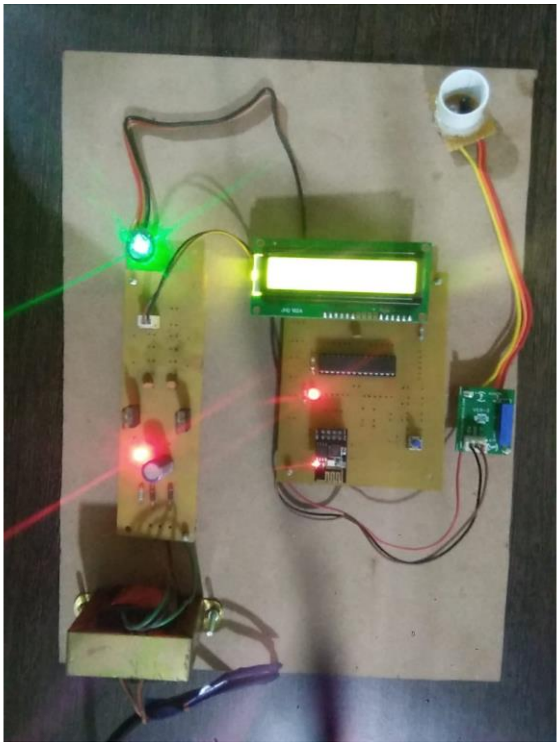

Fig 2

CONCLUSION

A real-time wireless respiratory monitoring system with coughing detection is presented for patient surveillance during ambulatory, hospital and home care. It uses low-power electronic building blocks and is designed to maximize the movement and comfort for the user with its small size circuit. Its set-up is much quicker and easier to use than the RIP used in hospitals since it doesn't need any synchronization. While the system is able to detect the coughing occurrence. The system can also be expanded to include cardiovascular, blood pressure and temperature monitoring units to increase diagnostic reliability. Future work will also include developing more robust algorithms to enable continuous breathing surveillance during different sports activity.

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