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# Wearable Polymer Optical Fiber Sensors in Healthcare using Iot

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***Abstract*** **- Sleep disordered breathing is an increasingly common condition among the general population. Life expectancy in most countries has been increasing continually over the several few decades thanks to significant improvements in medicine, public health, as well as personal and environmental hygiene. However, increased life expectancy combined with falling birth rates are expected to engender a large aging demographic in the near future that would impose significant burdens on the socio-economic structure of these countries. Therefore, it is essential to develop cost-effective, easy-to-use systems for the sake of elderly healthcare and well-being. Remote health monitoring, based on non-invasive and wearable sensors, actuators and modern communication and information technologies offers an efficient and cost-effective solution that allows the elderly to continue to live in their comfortable home environment instead of expensive healthcare facilities. These systems will also allow healthcare personnel to monitor important physiological signs of their patients in real time, assess health conditions and provide feedback from distant facilities. In this paper, we have presented and compared several low-cost and non-invasive health and activity monitoring systems that were reported in recent years. A survey on textile-based sensors that can potentially be used in wearable systems is also presented. Finally, compatibility of several communication technologies as well as future perspectives and research challenges in remote monitoring systems will be discussed.**

***Keywords***- **Home Sleep Study,Polysomnography, Smart Wearable's ,Sleep Disordered Breathing.**

## I. INTRODUCTION

Life expectancy has been increasing worldwide due to significant improvements in healthcare, and medicine, as well as due to growing consciousness about personal and environmental hygiene. In addition, over the past several decades, there has been increasing interest in family planning, thereby contributing to declining birth rates around the globe. According to the World Health Organization (WHO), by 2017, the elderly population over 65 years or older are expected to outnumber the children less than 5 years of age. However, this enormous aging population would create a significant impact on the socio-economic structure of society in terms of social welfare and healthcare needs.

Besides this, the cost associated with health care services continues to soar because of the increasing price of prescription drugs, medical instruments, and hospital care. Therefore, it is an utmost necessity to develop and implement new strategies and technologies in order to provide better health care services at an affordable price to the aging population or to the people of those areas having limited access to healthcare while ensuring maximum comfort, independence, and participation among the people. Remote healthcare monitoring allows People to continue to stay at home rather than in expensive healthcare facilities such as hospitals or nursing homes.

## II.WIRELESS POLYSOMNOGRAPHY INTELLIGENT SYSTEM FOR SLEEP MONITORING

Polysomnography (PSG) is considered the gold standard in the diagnosis of obstructive sleep apnea (OSA). The diagnosis of OSA requires an overnight sleep experiment in a laboratory. However, due to limitations in relation to the number of labs and beds available, patients often need to wait a long time before being diagnosed and eventually treated. In addition, the unfamiliar environment and restricted mobility when a patient is being tested with a polysomnogram may disturb their sleep, resulting in an incomplete or corrupted test.

Therefore, it is posed that a PSG conducted in the patient's home would be more reliable and convenient. The Internet of Things (IoT) plays a vital role in the e-Health system. In this paper, we implement an IoT-based wireless polysomnography system for sleep monitoring, which utilizes a battery powered, miniature, wireless, portable, and multipurpose recorder. A Java-based PSG

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recording program in the personal computer is designed to save several bio-signals and transfer them into the European data format. These PSG records can be used to determine a patient's sleep stages and diagnose OSA. This system is portable, lightweight, and has low power-consumption. To demonstrate the feasibility of the proposed PSG system, a comparison was made between the standard PSG-Alice 5 Diagnostic Sleep System and the proposed system. Several healthy volunteer patients participated in the PSG experiment and were monitored by both the standard PSG-Alice 5 Diagnostic Sleep System and the proposed system simultaneously, under the supervision of specialists at the Sleep Laboratory in Taipei Veteran General Hospital. A comparison of the results of the time-domain waveform and sleep stage of the two systems shows that the proposed system is reliable and can be applied in practice. The proposed system can facilitate the long-term tracing and research of personal sleep monitoring at home.

## III. BASIC STUDIES

The purpose of this research is to develop a portable wireless PSG system for sleep monitoring. In order to do this, a system to acquire and monitor/record the bio-signals in EDF format is needed, where the exchange format can be imported by other analysis software to score the sleep stage; so, it was divided into two parts: one is how to get the data for signal processing in the experimental environment and the other is to determine what this bio-signal means in scoring the sleep stage. The diagrammatic overview of the system is shown in Fig. 1

Fig.1. Diagram of wireless polysomnography system.

The core requirement of the device is to monitor cardiac and respiratory function. It further needs to be aware of body position and activity such that artefacts resulting from movement may be detected. Data needs to be captured, recorded and transferred to an external PC/Mobile Phone and subsequent Cloud for further analysis. Ultimately, the physiological signals intended to be extracted from the raw data are

1. Breathing pattern
2. Respiration effort
3. Cardiac activity
4. Body movement

The following features are required to obtain this raw data successfully.

1. Wireless unfettered operation.
2. Easy to don, comfortable to wear for long periods and easy to remove following use.
3. Small size and rechargeable with the ability to operate for at least 8 hours with a single charge.
4. An interface enabling a live stream of sensor data, allowing the user to determine if the sensors are working correctly before use.
5. A storage medium within the device to store all data captured from sensors to ensure data integrity.
6. An interface to enable transfer of data to a secondary device, e.g. phone, computer.

**1. Bio-Signals**

A polysomnogram will typically record a minimum of eleven channels requiring a minimum of 22 wire attachments to the patient. Two channels are for the EEG one or two measure airflow, one is for chin movements, one or more for leg movements, two for eye movements (EOG), one for heart rate and rhythm, one for oxygen saturation and one each for the belts which measure chest wall movement and upper abdominal wall movement.

Wires for each channel of recorded data lead from the patient and converge into a central box, which in turn is connected to a computer system for recording, storing and displaying the data. During sleep, the computer monitor can display multiple channels continuously. In addition, most labs have a small video camera in the room so the technician can observe the patient visually from an adjacent room.

The different types of electrical potentials are listed in Table 1 We describe the different biosignals of the electrode position and recorded signal, for example: this patient is wired up for an overnight sleep study (polysomnogram).

Table I: Medical and physiological parameters.

| Parameter | Principal Measurement Range of Parameter |
|---|---|
| EEG | 20uV-200uV |
| EMG | 10uV-5000uV |
| EOG | 50uV-3500uV |
| EKG | 0.5mV-4mV |
| Airflow | 0uV-2000uV |

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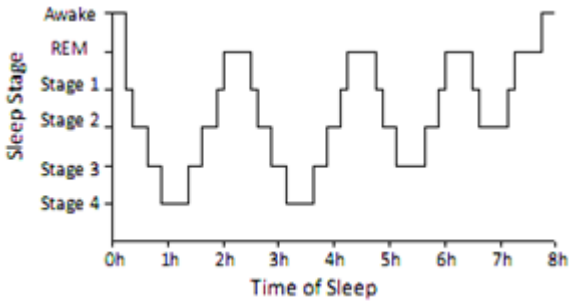


Fig.2. Sleep stage patterns.

**2. Sleep Stage**

According to the AASM Manual for Sleep Scoring, considered the world-wide standard in the medical community, sleep staging relies on three fundamental biopotentials: the brain wave activity measured by an EEG, the eye movement recorded via an EOG and the muscular tone measured by an EMG. The sleep structure is represented in a dedicated graph, called a hypnogram, which represents the course of the sleep stages of the patient overnight (see Fig. 2), and provides the clinician with relevant information for the diagnosis of sleep disorders.

NREM(non-rapid eye movement) sleep was divided into four stages, with slow-wave sleep comprising stages 3 and 4. In stage 3, delta waves made up less than 50% of the total wave patterns, while they made up more than 50% in stage 4. Furthermore, REM sleep was sometimes referred to as stage 5.

**3. Smart Wearable's**

The smart wearable's that are embedded into smart clothing can be classified according to diverse parameters

- Accessory wearables. They are low-power devices that are adapted to the human body in order to be worn as accessories like smart watches, smart glasses or fitness trackers.
- Textile/Fabric wearables. They integrate electronics into textiles through flexible fabrics. The European Center for Standardization categorized in 2011 this kind of wearable's, while defining them as functional textile systems that interact with its environment (i.e., they adapt or respond to changes in the environment).

**4. IOT (The Internet of Things)**

The Internet of Things (IoT) is a promising technology for smart applications, such as health monitoring and online data processing. The Internet of Things (IoT) has opened up a world of possibilities in medicine when connected to the internet; ordinary medical devices can collect invaluable additional data, give extra insight into symptoms and trends, enable remote care, and generally give patients more control over their lives and treatment. However, the major concern about IoT deployment is data security and energy efficiency. To address this issue, we focus on developing an IoT framework-based sleep monitoring system.

## IV. PORTABLE BIO-SIGNAL ACQUISITION SYSTEM

In our experimental environment, the user wears a portable acquisition system developed to continually obtain multiple bio-signals during the period of overnight sleep. This portable acquisition system is a battery-powered and wearable module. It is easy to set up and is comfortable for the users. First, multiple bio-signals are continually measured by our portable acquisition module. After amplifying tiny multiple bio-signals, all noise except the frequency band of multiple bio-signals is removed by the filters in our portable acquisition module. Then, filtered multiple bio-signals are digitized by the analog-to-digital converter, and are transited to the PC via Bluetooth. The PC-based software is development by JAVA to receive digitalized raw data from our portable acquisition module to decode raw data, to display raw data in real-time and to save raw data in standard format. The saved records can be transmitted to a hospital via the network, and can be analyzed by autoscoring software and validated by the clinician.

An analysis of the autoscoring software and the validation of the clinician simplify the PSG test, and allow the sleep monitoring of patients to be conducted in their homes. Our portable PSG system is easier and more comfortable for the patient and enables more familiar and normal sleep habits.The portable biosignal acquisition unit comprises four parts:(1) front-end filter circuit, (2) analog to digital con- verter and digital controller, (3) power management circuit and (4) wireless transmission. A diagram of the portable biosignal acquisition unit for various kinds of biosensors as shown in Fig. 3, which indicates the voltage and frequency ranges of some common biopotential signals.

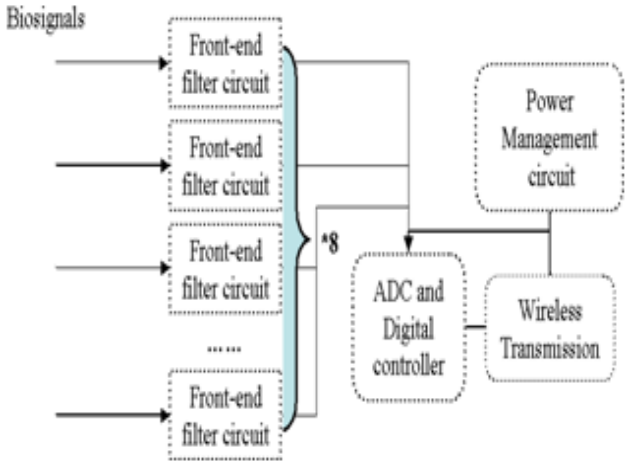


Fig.3. Diagram of portable biosignal acquisition unit.

Table II: The specifications of the portable biosignal acquisition unit.

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| Type | Portable biosignal acquisition unit |
|---|---|
| Operating Temperature | -40° to +85°C |
| Size | 65 x 50 x 8 $mm^3$ |
| Weight | 33 g(with battery)<br>66 g (with battery and box) |
| Channel Number | 8 |
| power | Rechargeable Lithium 3.7V 450mAh |
| Gain | Depend on difference channel |
| Bandwidth | Depend on difference channel |
| Input signal range | Depend on difference channel |
| ADC Resolution | 12bits |
| Power capacity | 16~20hours |
| Sampling rate | 2048Hz up to 200kHz |
| Communication Interfaces | Bluetooth 2.0 |

A visualization of the system architecture is shown in Fig. 4 based on the system requirements.

Fig.4. Abstract system architecture.

To embed the electronics inside the t-shirt fabric, the hardware must be as small and thin as possible.

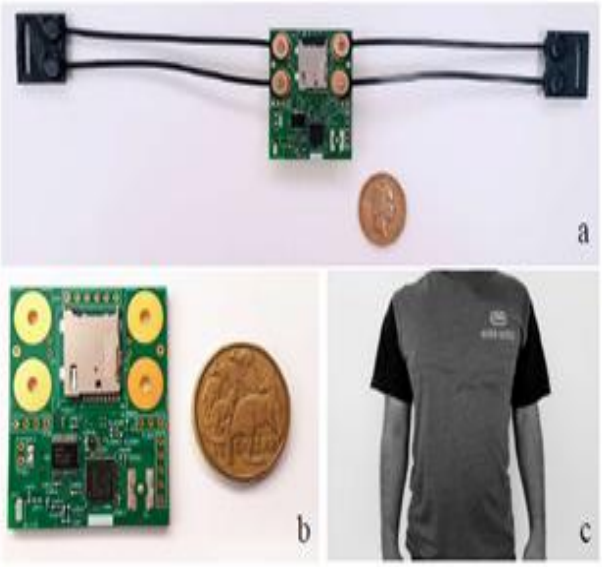


Fig.5. Electronic PCB and ERB sensor. (b) PCB for Vital Core main controller unit. The SD card, ADC, MCU and Antenna are placed on the top side of the board. (c) Vital core prototype when electronics are attached to the rear side of the fabric using interfacing fabric.

The hardware is manufactured in a 40 mm x 41 mm four layer PCB as shown in Fig. 5. The device is three times smaller than the Nox T3 and 3.8 times smaller than Apnealink Air which are considered as the smallest at-home sleep diagnostic devices in the market. Custom made U- shaped ERBs connect to the two sides of the circuit board such that chest expansion is divided between two bands. This allows respiration recording even while the user lies on their side. The PCB is coated with circuit board lacquer to protect from sweat and concealed under the tshirt such that the PCB part placed just below the sternal bone, where both male and female human body naturally have a small gap under the rib cage. The only rigid part of the device is placed to occupy this space. Even when the user sleeps in a prone position, there is a minimum chance that the device is perceived by the user. Fig. 5. shows the front side of the device when ERBs are attached.

The ECG channels are not intended to be used in the home environment as cardiac activity will be captured using the noncontact ERB, thus negating the need for any electrodes. However, it is useful in validating the device and potentially will be used in future application to gain additional information about cardiac activity. The connections to the disposable ECG electrodes can be routed via either jumper wires or shielded low resistive EMI fabric. The electronics and ERBs were attached to the internal side of a t-shirt fabric using an “interfacing” technique popular in garment manufacturing.

With interfacing fabric, we can connect the device and ERBs without any woven threads. When attached, the electronics and sensors are almost invisible as shown in Fig. 5. A series of device test experiments were performed to assess the overall performance of the device. First we assessed technical aspects of the device, i.e. data throughput via Bluetooth, SD card throughput, power consumption. Second, we assessed functional capabilities, i.e. respiration and cardiac activity detection. For all experiments, the data is sampled at 100Hz for each channel, ERB1, ERB2, ECG and ccelerometer. Each sample consists of a 32bit integer.

## V. CONCLUSION

In this paper, the design and implementation of a health monitoring medical device for recording the heartbeat and Respiration rate based on an indirect approach was described. Also, the system consists of a medical sensor as well as a central node which is used to transfer the measurement results to a PC. Also, the monitoring system can be used for monitoring the signs related to the

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patient's heart and lungs health such heartbeat, respiration as well as the duration of inhalation and exhalation.

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