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Designing a System that Records the Sleeping Position Data of Sleep Apnea Patients

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Anahtar Kelimeler: Uyku apnesi, Vücut pozisyon sensörü, STM mikrodenetleyici, ADC, USB

ABSTRACT

Sleeping positions have a significant impact on exposure of apnea patients to sleep apnea. In this study, the sleeping position of the patient was read with the STM microcontroller by using the body position sensor (SleepSense 1/8" Plug DC Body Position Sensor Kit) produced by the sleep sense company. This sensor produces results with analog signals between 0-2V. This analog signal was read using the ADC (Analog Digital Converter) feature of the microcontroller. This signal read by the microcontroller was sent to the computer via the USB port. The C# software prepared on the computer reads the data from the microcontroller and saves this data and the arrival time of the data to the bit TXT file. The data in this TXT file is ready to be evaluated by signal processing methods. These data, together with other data obtained from the polysomnography device, can be used to learn the body position of the patient at the time of apnea.

Uyku Apnesi Hastalarının Uyku Pozisyonu Verilerini Kaydeden Bir Sistem Tasarımı

ÖZ

Uyku apnesi hastalarının apneye girmelerinde yatış pozisyonlarının önemli bir etkisi vardır. Bu çalışmada sleep sense firmasının üretmiş olduğu vücut pozisyon sensörü (SleepSense 1/8" Plug DC Body Position Sensor Kit) kullanılarak hastanın yatış pozisyonu STM mikrodenetleyicisi ile okunmuştur. Bu sensör 0-2V arasında ürettiği anolog sinyallerle sonuç üretmektedir. Bu analog sinyal mikrodenetleyicinin ADC özelliği kullanılarak okunmuştur. Mikrodenetleyici tarafından okunan bu sinyal USB port üzerinden bilgisayara gönderilmiştir. Bilgisayarda hazırlanan C# yazılımı mikrodenetleyiciden gelen verileri okumakta ve bit TXT uzantılı dosyaya bu verileri ve verinin geliş saati ile birlikte kaydetmektedir. Bu TXT uzantılı dosya içerisindeki veriler sinyal işleme yöntemleri ile değerlendirilebilmek için hazır hale gelmiştir. Bu veriler, polisomnografi cihazından elde edilen diğer veriler ile birlikte hastanın apneye girdiği anlardaki vücut pozisyonu öğrenmek için kullanılabilecektir.

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1. Introduction

Many patients with obstructive sleep apnea (OSA) exhibit worsening event indexes when lying on their back[1, 2]. If indices become normal during non-supine sleep, positional therapy is an option. Although a variety of methods are available for patients choosing positional therapy, monitoring of compliance remains somewhat difficult, as the reliability of self-reported sleeping position is uncertain[1]. The data produced by PAP (Positive Airway Pressure) devices used by millions of patients around the world can be considered as Big Data. This large data can be used to diagnose undiagnosed sleep apnea and will also be useful in studies of personalization of treatment [3]. As an alternative to the polysomnography method used in the diagnosis of obstructive sleep apnea, home examination and analysis can be performed [4]. APAP (Automatic Positive Airway Pressure) devices need to predict obstructive sleep apnea and analyze the pattern of respiratory flow to adjust pressure parameters [5]. In the master's thesis prepared by Çakmak (2018), a mobile device was developed that can share data during sleep with patients and doctors in the detection of sleep apnea [6]. Agrawal et al. (2017) studied the correlation between the AHI (Apnea Hypopnea Index) values obtained with the PAP device and the AHI values obtained from the PSG (Polysomnography) system in the sleep laboratory [7].

Implanted biomedical devices [8, 9] have the potential to make a revolution in medicine. These devices need the ability to communicate with an external computer system (base station) via a wireless interface. The limited power and computational capabilities of smart sensor-based biological implants present research challenges in various aspects of wireless networking due to the need to have a biocompatible, fault-tolerant, energy-efficient and scalable design [10]. Biomedical sensors are vital in modern life. We live in an era of computerization for every aspect of life. As we all know, computers can only process data. Data should be collected, stored if necessary and transferred to a computer. Biomedical sensors are designed to collect data. It may be necessary to collect data for patients staying in a hospital or at home, or for outpatients [11].

In this study, an electronic system was designed to collect data on the body position sensor. STM microcontroller reads the data from the sensor and sends this data to the computer via USB port. The software developed for the computer also saves these incoming data to a txt file for later evaluation.

2. Material and Method

In this study, a device that records the patient's lying position during the night was designed using an embedded computer system with a STM32f407 microcontroller, according to criteria such as affordable price, processor performance, number of ports, communication protocols and widespread document support. This designed device will be used with the polysomnography device that records the patient's apnea data during the night. While the polysomnography device is used to determine the moments when the patient enters apnea during the night, the designed device determines the lying position of the patient at the time of apnea.

2.1. Embedded system used in the study

In this study, an embedded computer system with STM32f407 microcontroller was used to read and evaluate the analog data coming from the body position sensor and send the results to the computer via USB port.

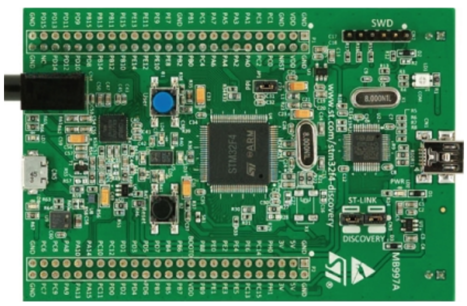


Figure 1. STM32f407 discovery board used in this study

The features of the embedded system used for this device are as follows [12]:

- Microprocessor: 32-bit Arm® Cortex®-M7 L1 cache: 16 Kbytes data and 16 Kbytes command cache, dsp comman support, 400 MHz, MPU, 856 DMIPS
- External memory support: SRAM, PSRAM, SDRAM/LPSDR SDRAM, NOR/NAND Flash memory
- Input/Output Ports: At least 168 interrupt ports
- Communication Protocols: 4× I2Cs, 4× USARTs/ 4x UARTs, 6× SPIs, 1x I2S, SWPMI single-wire protocol master I/F, 1× SD/SDIO/MMC, interfaces (up to 125 MHz), 1× USB OTG interfaces
- Timer: 10×16-bit timers, 1× high-resolution timer (2.5ns çözünürlük), 2×32-bit timers, RTC (built-in real time clock)
- Analogue features: 3× ADCs 16-bit 16-bit resolution (Can be reproduced up to 32 channels), 2× 12-bit D/A converters, Dma feature: 1× high-speed, 2× dual-port DMA, Memory requirement: 2 Mbytes of flash drive and 1 Mbyte

2.2. Body position sensor used in the study

Body position sensor, which is also used in polysomnography systems, was used to learn the lying position of the patient during sleep. 1/8" Plug DC Body Position Sensor Kit produced by SleepSense company was used as body position sensor. Figure 2 shows an image of this sensor. The body position sensor gives the patient's lying position (supine, prone, left, right or sitting) as a dc voltage level. This information is read using the ADC feature of the STM microcontroller. The analog data produced by the Body Position sensor was converted into 12-bit digital data with the ADC feature of the microcontroller and read. This 12-bit digital data has been converted into the patient's lying position data in accordance with the information given in the sensor data sheet. An example of this data is given in Figure 5.

Figure 2. The body position sensor used in this study [13]

The computer software prepared with C# to read the data coming from the embedded system via the USB port and save these data with the arrival time is given in Figure 3.

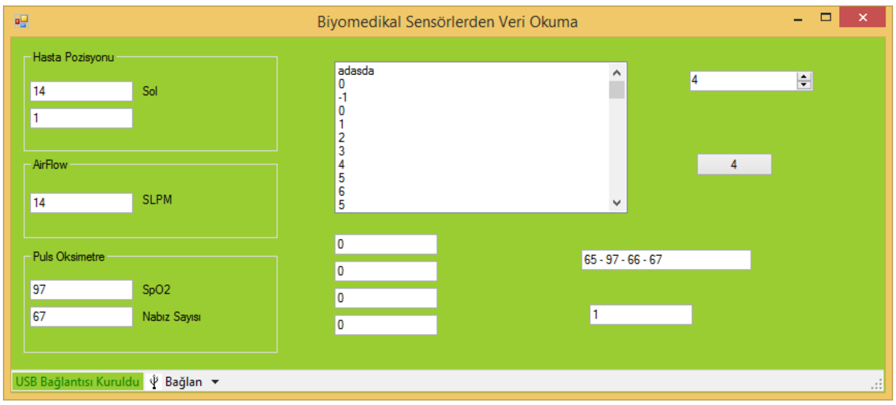
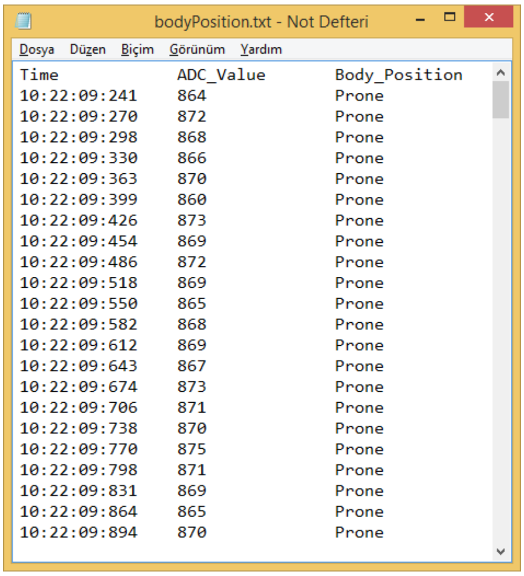


Figure 3. Computer software

While using the embedded computer system and data reading card, it is aimed to develop a data reading system similar to that used in polysomnography systems in the hospital. This is a necessity in order for the signal processing and artificial intelligence software developed with ready-made patient data obtained from the hospital to work in harmony with the instantaneous data obtained from the patient. In this respect, the sensor data obtained as analog has been transferred to the computer environment as digital data in the same format and frequency as the outputs of the polysomnography system.

3. Results and Discussion

In polysomnography devices, data is read at 32Hz frequency from the body position sensor. In this study, 32 data is read per second from the body position sensor. For this, the timer interrupt of the microcontroller is used. In Figure-4, an example of a txt file where the data from the body position sensor is recorded is given. As can be understood from this file, the file contains the time the data was recorded, the ADC value produced from the sensor, and the patient's lying position information obtained from this ADC value.


bodyPosition.txt - Not Defteri

Dosya Düzen Biçim Görünüm Yardım

Time	ADC_Value	Body_Position
10:22:09:241	864	Prone
10:22:09:270	872	Prone
10:22:09:298	868	Prone
10:22:09:330	866	Prone
10:22:09:363	870	Prone
10:22:09:399	860	Prone
10:22:09:426	873	Prone
10:22:09:454	869	Prone
10:22:09:486	872	Prone
10:22:09:518	869	Prone
10:22:09:550	865	Prone
10:22:09:582	868	Prone
10:22:09:612	869	Prone
10:22:09:643	867	Prone
10:22:09:674	873	Prone
10:22:09:706	871	Prone
10:22:09:738	870	Prone
10:22:09:770	875	Prone
10:22:09:798	871	Prone
10:22:09:831	869	Prone
10:22:09:864	865	Prone
10:22:09:894	870	Prone

Figure 4. Reading data from body position sensor

Figure 5 shows the data samples read from the body position sensor, which is an analog sensor. As can be seen from this graph, while the patient is lying in the supine position, it produces analog values between 582 and 593 from the ADC, while the patient is lying on their right side, it produces analog values between 1077 and 1102, while lying on the left side, it produces analog values between 267 and 277, and when lying in the prone position it produces analog values between 861 and 881.

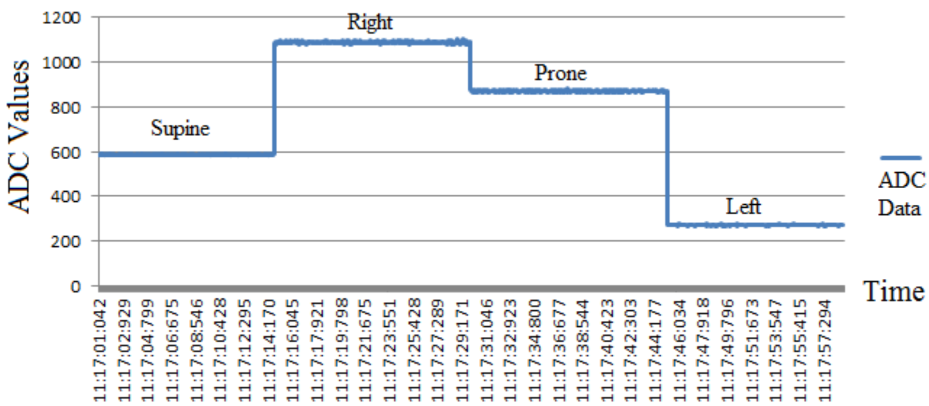


Figure 5. Examples of data read from body position sensor

With polysomnography devices, the patient's EEG, Jaw EMG, EOG (Right and Left eye movements), Snoring sound, ECG (2 channels), Impedance Data, PTT Signal, Pressure Flow (Ora-Nasal airflow pressure), SPO2 (Oxygen saturation)), Light sensor, PLM (leg movements), Pressure Snore, Thorax (Abdominal and chest movements) and Heart Rate data are read. With these data, the moments when the patient enters apnea can be detected. With the body position sensor, the lying position of the patient at the time of apnea can be determined.

4. Conclusion

In this study, the use of a body position sensor was proposed to determine the lying position of sleep apnea patients at the time they entered apnea. The body position sensor used in this study produces analog data in mV. These data are increased to Volt level with filter circuits and are free from noisy data. The analog data at the output of the filter circuit were read with the ADC feature of the microcontroller and converted into position information. The data obtained at the end of this study showed that body position sensors are suitable for determining the lying position of the patient during apnea.

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Conflict of Interest Statement

The authors declare that there is no conflict of interest.

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