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3D Monitoring of Lying Position for Patients with Positional Sleep Apnea Syndrome

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Abstract – In this study, a data acquisition system that monitoring and recording of the position data of the patients is designed. For this work, a circuit with microcontroller is designed and an acceleration sensor which has ability to define position by using 3-axis cartesian coordinate systems is used. The data obtained from the sensor are recorded on a SD card and transferred to a computer via USB in real time. The data transferred to the computer can also be saved in a text file in order to use in MATLAB program to investigate both time and frequency analyzes. These data which are received to the computer, are grouped to the axis and plotted the position by the computer interface program which is developed at MATLAB-Gui programming language. Patient position can be detected as 3D real time. This ability gives us advantage to detect of patient's lying posture for positional sleep apnea study. It is very important that developed system for infants, elderly and disabled individuals with positional sleep apnea disease especially, can easily use to the detection of the position of the lying. They can determine the most ideal sleeping position for themselves. So, the developed system is portable and it can be used for a number of other study and research.

Keywords - *Lying position, positional sleep apnea syndrome, acceleration sensor, 3D animation, microcontroller.*

1. Introduction

A change in the body position causes also a change in the position of the heart, manifested in the ECG as a change in morphology of the QRS complex and the ST–T segment. Such changes are particularly problematic in ambulatory ST monitoring since they may cause

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false ischemia alarms. Hence, it is important to develop techniques which discriminate body position changes from true ischemic episodes [1].

Likewise, Many methods are used to detect body movements due to different positions during sleeping [2, 3]. In particular, determining of the patient's position for sleep apnea disease is very important. Because, the risk of sleep apnea is higher at the person who lying on the wrong sleeping position.

The sleeping positions of the patient can trigger to apnea or hypopnea. Usually at the supine sleeping position, the apnea-hypopnea index (AHI) increases, while AHI rate decreases at the lying left or right positions. It is mentioned positional apnea, at the case of AHI the rate is decreased by half in other positions during sleeping. Positional sleep apnea patients are lying at the position of supine in the longest time [4]. This situation constitutes a major risk for the patients.

The respiratory events also varies according to the patient lying position. In different positions, the volume of air entering the lungs varies, therefore Respiratory rate also varies [5]. To lie in the same position for a long time can cause some respiratory diseases.

The Lying position is closely related to snoring. Especially in overweight males, intrathoracic pressure increases due to pressure caused by abdominal mass on the diaphragm. The snoring occurs at the case of shifting the tongue back and with the relaxation of the soft tissues and muscles that around the pharynx during sleeping. A simple snoring is positional initially and occurs in the supine position. But the snore can occur in any position due to gain in weight and the increased upper airway obstruction [6].

Sleeping position is also very important for babies. The baby can return on the face during sleep and can drown in own saliva because of swallowing feature is not development. So it must put to sleep the baby at supine position. Baby position should be continuously monitored [7].

Although the various sensors (such as pressure sensor array) are used to detect the sleeping position [8], the accelerometers are also used quite often in recent times [9-10-11-12].
As seen in the results of the literature review, the sleeping position is an important issue. Lying on the wrong body position can cause many diseases about respiratory and arthritic.

In this study, we present a system which can detect the position of the lying for positional sleep apnea patients and may offer real-time animation of 3-D images of the patients.

Our system seems to measure and record the movements of sleep position with great reliability and inexpensive, portable, easy to use.

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2. Method

At present, the patient position information is determined with the help of the in the PSG (polysomnography) device. The PSG is the most commonly used test to diagnosing sleep-related breathing disorders and is considered as gold standard [13].

PSG has a lot of equipment and measurements are carried out overnight on patients with this equipment which included electroencephalogram, electrooculogram, electromyogram (submental region and bilateral anterior tibialis muscle), airflow (nasal pressure and thermistor), respiratory effort of thorax and abdomen (inductance plethysmography), and oxyhemoglobin saturation(SpO_2), snoring, body position, and video monitoring [14].

The measured data are recorded in the paper and the computer on continuous forms simultaneously. Fig. 1 shows a patient's PSG sleeping records;

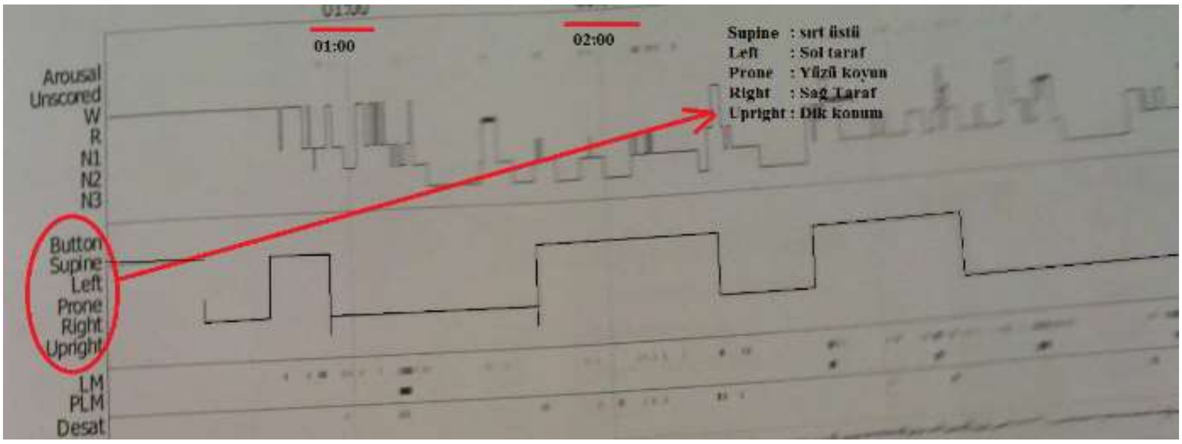

Figure 1. Obtaining of information of the position of the patient from the PSG device

As seen, patient positions are grouped by time and can clearly be seen what position and which time the patient is lying. Unfortunately, discomfort of the electrodes and the high amount of information requed, it makes the PSG is an expensive and consuming procedure.

A data acquisition card with an Arduino microcontroller and 3 different software are developed to determine the patient position and to visualization of the position the real-time. Arduino become quite a popular software recently in terms of providing to open source code and ease of use [15]. The axis and angle data are read by using Arduino software (V.1.6.4) from gyu-521 sensor, recorded on a SD cart and are visualized using processing software (V 3.0.1) as 3D.

In addition, an interface program has been prepared using the Matlab-Gui (Va. 7.12.0.635 (R2011)) in order to plotting of the graph of the data received from the sensor and to analyze the time axis. Thus, the data recorded on the SD card can be analyzed graphically if desired. Thus, the total number of times during sleep, the patient position changes, information of longer sleep at which position etc., can be easily analyzed.

2.1. MEMS Technology

Micro-**E**lectro-**M**echanical **S**ystems(MEMS), is a technology that in its most general form can be defined as miniaturized mechanical and electro-mechanical elements that are made using the techniques of microfabrication[16]. MEMS-based accelerometers can be produced with different techniques[17-18].

Fig. 2 shows a monolithic MEMS production and utilization areas.

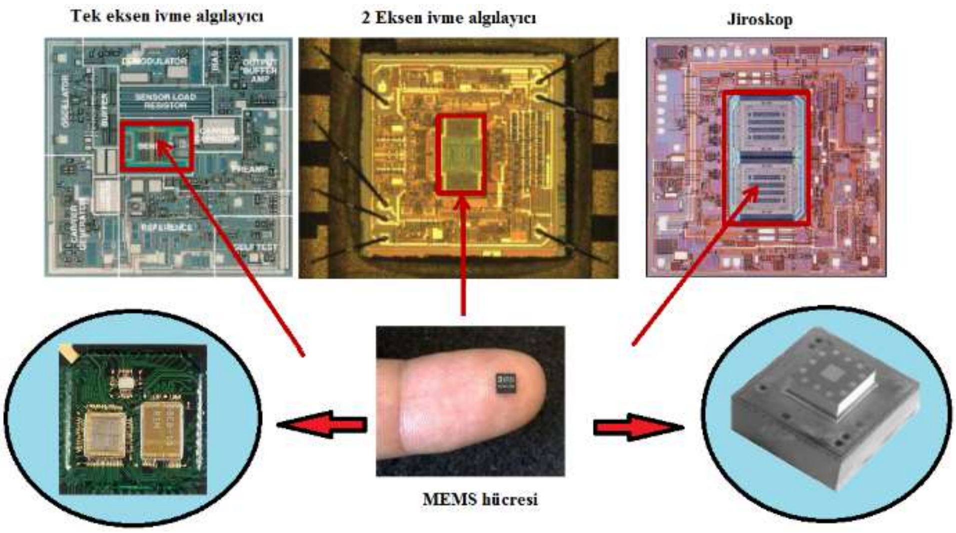

Figure 2. Monolithic MEMS production and utilization areas[19].

Altought the MEMS technology is used quite frequently in many different applications [20-24], it has increased enormously to use in the biomedical fields in recent years. In many areas about health like measuring of diaphragm movements [25] it is utilized from these sensors. Thus, with the aid of this technology, new systems can be designed in the diagnosis of certain diseases.

2.2. Accelerometer and Gyroscope pair (GY-521)

The GY-521 sensor hosts an acceleration sensors (MPU6050) and a gyroscopes (MPU-6000). Three-axis MEMS gyroscope with digital output can be read and angular velocity that ranging ± 500, ± 1000 and ± 2000°/sec at the X, Y and Z-axis can measured with the development of appropriate hardware connection and software. Likewise, three-axis MEMS acceleration sensor outputs(X, Y and Z-axis digital outputs) can be read ranging ± 4g ± 8g and ± 16g [26].

Thus, with the help of a single sensor, both axial acceleration values in a three-dimensional coordinate system and angular velocity values can be read easily.

2.3. Triple-Axis tilt and angle calculation

The classical method of rectangular (x, y, z) to spherical (ρ, θ, φ) conversion can be used to relate the angle of tilt in the xy-plane, θ, and the angle of inclination from the gravity vector, φ, to the measured acceleration in each axis, as follows:

$$\theta = \tan^{-1}\left(\frac{A_{X,OUT}}{A_{Y,OUT}}\right) \qquad (1)$$

$$\phi = \cos^{-1}\left(\frac{A_{Z,OUT}}{\sqrt{A^2{}_{X,OUT} + A^2{}_{Y,OUT} + A^2{}_{Z,OUT}}}\right) \tag{2}$$

Given the assumption that the only measured acceleration is due to gravity, the denominator of the operand in Equation 2 can be replaced with a constant, ideally 1, because the RSS value of all the axes is constant when the only acceleration is gravity. The angles are shown in Figure 11, where Figure 11c shows θ only in the xy-plane, and Fig. 3 shows φ as the angle between the z-axis and the gravity vector.

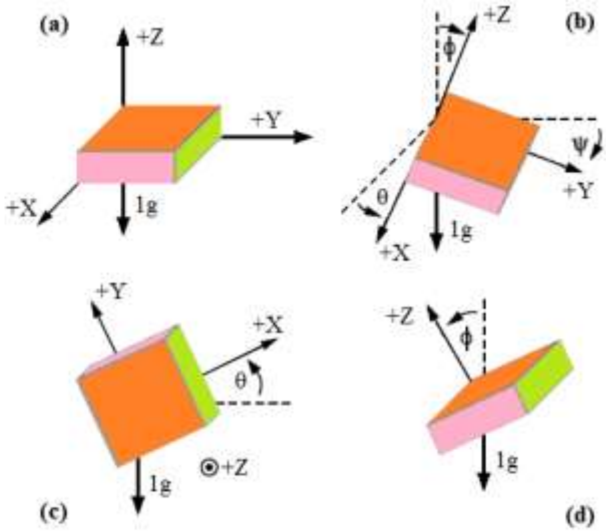

Figure 3. Tilt and angle calculations between axis [27].

Basic trigonometry can be used to show that the angles of incli-nation can be calculated using Equation 3, Equation 4, and Equation 5 [27].

$$\theta = \tan^{-1}\left(\frac{A_{X,OUT}}{\sqrt{A^2{}_{Y,OUT} + A^2{}_{Z,OUT}}}\right) \tag{3}$$

$$\psi = \tan^{-1}\left(\frac{A_{Y,OUT}}{\sqrt{A^2{}_{X,OUT} + A^2{}_{Z,OUT}}}\right) \tag{4}$$

$$\phi = \tan^{-1}\left(\frac{\sqrt{A^2{}_{X,OUT} + A^2{}_{Y,OUT}}}{A_{Z,OUT}}\right) \tag{5}$$

There are many studies in the literature associated with sensor placement and coordinates[28-30].

Especially, in the detection of respiratory parameters and the position of patients with the help of the wearable belt, it has been made recently in many important studies in the literature [31-34]. So, it has been decided that the best place to determine the position is the chest area (thorax). The acceleration sensor was attached with a belt in thorax.

When people stand up, a gravitational acceleration g will be generated in Z axis due to the earth gravity y(black coordinate). When people incline, a new gravitational acceleration g' will be measured (red coordinate) in the new Z axis (see Fig. 4).

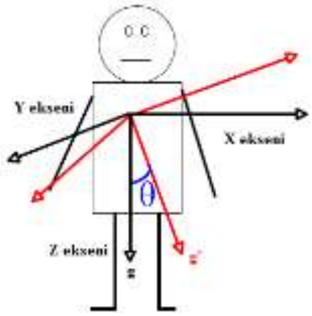

Figure 4 Human coordinate system [35]

In this case, g' value can be measured with a three-axis accelerometer in real time and the inclination angle θ can calculated using the above equations.

2.4. Design of Measurement Device

The designed system consists of many parts. Fig. 5 shows a block diagram of the designed and realized system.

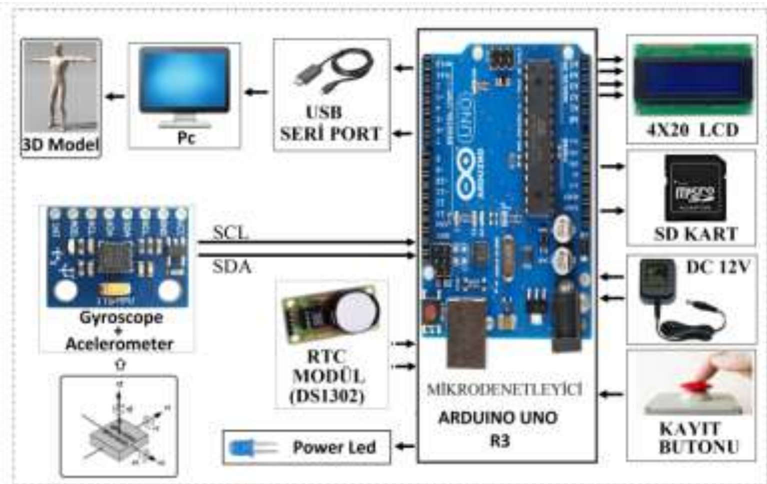

Figure 5 the block diagram of designed and realized system

I^2C protocol is used to transfer data between the GY-521 and the Arduino, because it allows very fast data transfer. This protocol is the short-distance protocol which provide a variety of peripheral devices to communicate with a minimum of external hardware and it has a simple, low bandwidth. Most of the existing I^2C device work up 400 kbps speeds. RTC module is located on the system to showing the real-time clock. With this module, the position information of patients can be measured in real-time.

An interface program is developed by using the design tool (GUIDE) in MATLAB program in order to transfer the acceleration values (X, Y and Z) and information indicating the patient motion axis YPR (Yaw, Pitch, Roll) parameters to the computer as given in Fig. 6. In addition, MATLAB program (version 7.12.0.635 (R2011a) 32-bit win32) has been also used for data interpretation and filtering.

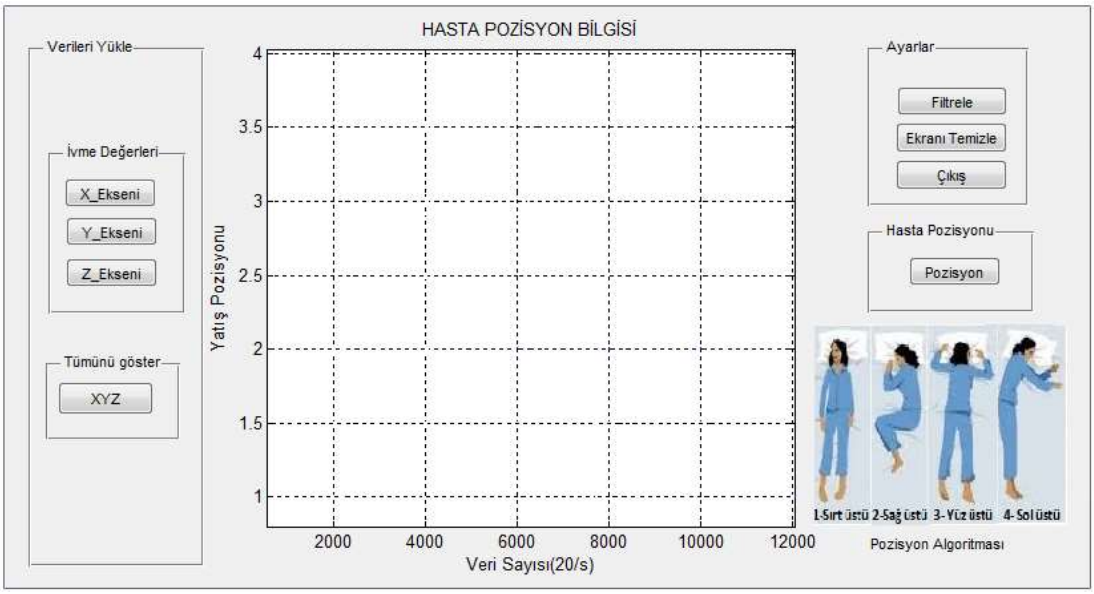

Figure 6. Interface program

3. Results

At first, the developed device was located on the patient's body and static acceleration values were obtained for five different positions. The position information was coded as shown in Fig. 7 and program algorithm was created accordingly. The acceleration values vary during position changes. In this case, the position information has been accepted as ‘0’.

Figure 7. The Patient lying positions and position information [36]

Table 1 shows position information in accordance with the range of the axis acceleration.

Table 1: The position information in accordance with the range of the axis acceleration.

POSITION	**POSITION INFORMATION**	**AXIS ACCELERATION RANGES (g)**		
		X	**Y**	**Z**
Supine	1	[0.3, -0.3]	[0.3, -0,3]	[1.25, 0.75]
Right	2	[0.3, -0.3]	[1.25, 0.75]	[0.4, -0,4]
Prone	3	[0.3, -0.3]	[0.3, -0.3]	[-0.25, -1.75]
Left	4	[0.3, -0.3]	[-0.25, -1.25]	[0.3, -0.3]
Sitting	5	[-0.25, -1.25]	[0.3, -0.3]	[0.3, -0.3]

***For all other situations Position => 0** (this information was used during position changes)*

Fig. 8 is a graphical representation of the recorded patient position information in the SD card. Accordingly, the patient has changed about position 26 times.

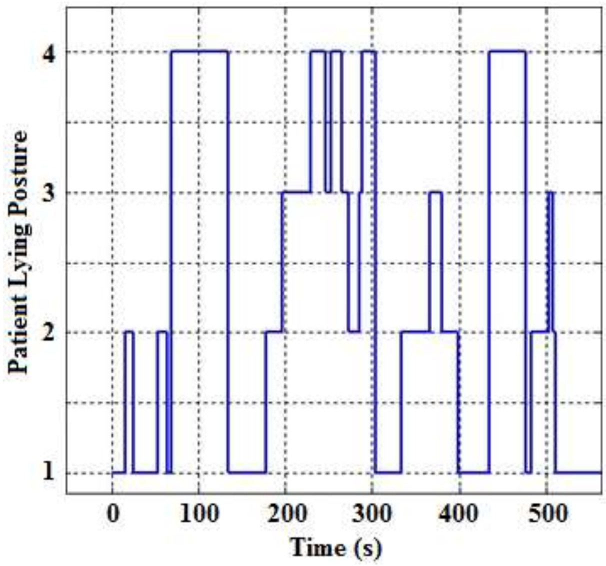

Figure 8. Obtaining information of the patient position

Later, an animated figure (see Fig. 9) was developed using processing program representing patients. Here, accompanied by information received through the patient, lying position can be monitored in real time over this figure. When creating real-time animation YPR (Yaw, Pitch, Roll) parameters were used.

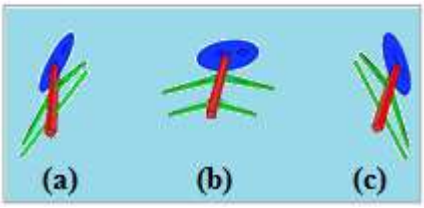

Figure 9 Patient position animation. (a)upper right, (b) supine (c) left.

In this study, a system was developed that can monitor the movements of patients and patient lying posture in real time as 3D during sleeping.

It is expected that the patients (especially the patients with positional obstructive sleep apnea syndrome) can use this system in own home and save own the position information to analyze. Because, the one way of getting rid of positional sleep apnea disease is not to lying of this position. For this, you need to know the position which apnea occurs. So the patients will be able to test for themselves which is in conformity with sleeping position.

The developed system is also very important for individuals with snoring. Because, the position of the patient's snoring can be easily determined by means of the system developed.

As result, it is very important that developed system for infants, elderly and disabled individuals with positional sleep apnea disease especially, can easily use to the detection of the position of the lying. So they can determine the most ideal sleeping position for themselves.

This work is quite practical, affordable, and effortless and has a life-saving role and increases the quality of sleep of people.

4. Conclusion

This paper presents the design and development of a system that can determine lying position. Specifically, different methodologies for lying posture classification were evaluated using the pressure sensitive bed. By continuously monitoring the lying posture with interface measurements, potential position with risk will be identified and appropriate interventions can be implemented. The design, implementation and evaluation of lying posture approach and methodologies are presented in details. Lying posture has been determined correctly and could be displayed in real time as 3D.

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References

[1] A.Mincholéa, L.Sörnmob, P.Laguna, Detection of body position changes from the ECG using a Laplaciannoise model, Biomedical Signal Processing and Control 14, pp:189–196, 2014.

[2] M. Aström, j. Garcia, P. Laguna, O. Pahlm, detection of body position changes using the surface electrocardiogram, Med. Bio. Eng. Comput., 41, 164-171, 2003.

[3] Jing Jia, Gongming Xu, Xi Pei, at al, Accuracy and efficiency of an infrared based positioning and tracking system for patient set-up and monitoring in image guided radiotherapy, Infrared Physics & Technology 69, pp:26–31, 2015.

[4] http://uykubozuklugu.uludag.edu.tr/ltrt014.htm, (02.09.2015, 22:20)

[5] H.Sümbül, A. H.Yüzer, İvmealgılayıcı Kullanarak Farklı Pozisyonlara Göre Soluma Sinyallerinin Elde Edilmesi, SİU2015, Sinyal İşleme Ve İletişim Uygulamaları Kurultayı, 16 - 19 May 2015,Processing v. 1, pp:279-282, İnönü Üniversitesi, Malatya, TÜRKİYE.

[6] http://www.memorial.com.tr/rehberler/saglik_rehberi/horlama-nedir/, (02.12.2015, 12:25)

[7] http://www.medikalakademi.com.tr/bebeklerde-uyku-pozisyonu-nasil-olmali/, (21.12.2014, 20:05)

[8] J. Pino Esteban, A. Mor´an Alejandra, Astrid D¨orner De la Paz and Pablo Aqueveque, Validation of Non-Invasive Monitoring Device to Evaluate Sleep Quality, Conf Proc IEEE Eng Med Biol Soc. 2015 Aug;2015:7974-7. doi: 10.1109/EMBC.2015.7320242.

[9] H. Enamul, F. Dickerson Robert, A. Stankovic John, Monitoring body positions and movements during sleep using WISPs, Proceeding WH '10 Wireless Health 2010 Pages 44-53 ACM New York, NY, USA, doi:10.1145/1921081.1921088

[10] M. Ermes, J. Pärkka, J. Mantyjarvi, I. Korhonen, Detection of daily activities and sports with wearable sensors in controlled and uncontrolled conditions, IEEE Trans Inf Technol Biomed. 2008 Jan;12(1):20-6. doi: 10.1109/TITB.2007.899496.

[11] A. Louis, L.Benny, K. Rachel, Y. Guang-Zhong, Sensor Placement for Activity Detection using Wearable Accelerometers, Body Sensor Networks (BSN), 2010 International Conference on, DOI: 10.1109/BSN.2010.23

[12] G.K. Prisk, S. Verhaeghe, D. Padeken, H. Hamacher, M. Paiva., Three-dimensional ballistocardiography and respiratory motion in sustained microgravity, Aviat Space Environ Med. 2001 Dec;72(12):1067-74, PMID:11763106

[13] Min Ju Kim, Gha-Hyun Lee, Chun-Sik Kim, Woo Sung Kim, Yoo-Sam Chung, Seockhoon Chung, Sang-Ahm Lee, Comparison of three actigraphic algorithms used to evaluate sleep in patients with obstructive sleep apnea, Sleep Breath (2013) 17:297–304, DOI 10.1007/s11325-012-0689-z.

[14] P. Jéssica Fabia, S.S. Rogerio, F. Paula Martins de Oliveira, S.Denis Eduardo, B. Sergio Tufik, L., Is portable monitoring for diagnosing obstructive sleep apnea syndrome suitable in elderly population?, Sleep Breath (2013) 17:679–686, DOI 10.1007/s11325-012-0742-y

[15] https://www.arduino.cc/, son erişim: 21.12.2015

[16] https://www.mems-exchange.org/MEMS/what-is.html
[17] B. Sebastian, S. Axel, B. Stephanus, Three-Axes Monolithic Silicon Low-g Accelerometer, journal of microelectromechanical systems, vol. 9, no. 4, december 2000, pp:551-556, doi: 1057-7157(00)10873-X.
[18] A. D. Reis Filho Carlos, P. Pessatti Mudo, Jolo P. C. Cajueiro and Paulo A. Dal Fabbro, Elements for a Monolithically Integrated Rotation Imbalance Detector, Industrial Electronics, 2003. ISIE '03. 2003 IEEE International Symposium on, pp:897-900, doi: 10.1109/ISIE.2003.1267940.
[19] MEMS by ADI Innovative technology to measure movement and sound, The World Leader in High-Performance Signal Processing Solutions, Analog Device.
[20] Y. Zhenhe, L.Ying, Z.Qiaoxiang, L.Xue, A Falling Detection System with wireless sensor for the Elderly People Based on Ergnomics, International Journal of Smart Home Vol.8, No.1 (2014), pp.187-196, doi:10.14257/ijsh.2014.8.1.20.
[21] S.Jivko, S.Vladimir, S.Ritika, S.Alexander, Vibrotactile Recognition and Categorization of Surfaces by a Humanoid Robot, IEEE Transactions On Robotics, pp:1-10. 2011, doi: 10.1109/TRO.2011.2127130.
[22] K.Adil Mehmood, L.Young-Koo, Y. Lee Sungyoung, Tae-Seong Kim, A Triaxial Accelerometer-Based Physical-Activity Recognition via Augmented-Signal Features and a Hierarchical Recognizer, IEEE transactions on information technology in biomedicine, vol. 14, no. 5, september 2010, pp:1166-1172, doi: 10.1109/TITB.2010.2051955.
[23] M. Nolan, B. Madden, E. Burke, Accelerometer based measurement for the mapping of neck surface vibrations during vocalized speech., Conf Proc IEEE Eng Med Biol Soc. 2009;2009:4453-6. doi: 10.1109/IEMBS.2009.5333817.
[24] Y. Yurish Sergey, Practical Circuits and Interface Techniques for MEMS Accelerometers with Quasi-Digital Output, Sensors & Transducers Magazine (S&T e-Digest), Vol.58, Issue 8, August 2005, pp.352-359, ISSN:1726-5479.
[25] H. Sümbül, A. H. Yüzer, Measuring of Diaphragm Movements by using iMEMS Acceleration Sensor, International Conference on Electrical and Electronics Engineering, ELECO 2015, Processing, pp:166-170, Bursa, TÜRKİYE.
[26] MPU-6000/MPU-6050 Product Specification, 2012 http://www.seeedstudio.com/wiki/images/b/b1/MPU6050.pdf (son erişim: 20.12.2015 23:41)
[27] J. Fisher Christopher, Using an Accelerometer for Inclination Sensing, AN-1057 Application Note, Analog Device, 2010.
[28] R.David Barbosa, L. Rojas Ojeda Juan, F. Crespo Foix Luis, M.Daniel Sánchez, A. Fernández Miguel, Mapping the Human Body for Vibrations using an Accelerometer, Engineering in Medicine and Biology Society, 2007. EMBS 2007. 29th Annual International Conference of the IEEE, pp: 1671-1674, 2007.
[29] W.Woranat, Q. Le Trung, T.S. Bukkapatnam Satish, Wireless Wearable Multi-Sensory System for Monitoring of Sleep Apnea and Other Cardiorespiratory Disorders, 2013 IEEE International Conference on Automation Science, and Engineering (CASE), pp: 605-610, doi: 978-1-4799-1515-6/13/$31.00 ©2013 IEEE
[30] G. Illapha Cuba, G. Bonomi Alberto, Identifying Types of Physical Activity With a Single Accelerometer: Evaluating Laboratory-trained Algorithms in Daily Life, IEEE transactions on biomedical engineering, vol. 58, no. 9, pp: 2656-2663, 2011, doi: 10.1109/TBME.2011.2160723.
[31] Wu Dan, Wang Lei, Zhang YT, Huang BY, Wang Bo, Lin SJ, Xu XW, A wearable respiration monitoring system based on digital respiratory inductive

plethysmography, Conf Proc IEEE Eng Med Biol Soc. 2009, pp: 4844-7. doi: 10.1109/IEMBS.2009.5332665.

[32] D. Hung Phan., S. Bonnet, R. Guillemaud, E. Castelli, Pham. Thi. N. Yen, Estimation of respiratory waveform and heart rate using an accelerometer, Conf Proc IEEE Eng Med Biol Soc., 2008, pp:4916-9. doi: 10.1109/IEMBS.2008.4650316.

[33] M. Chan Alexander, F.Nima, N.Ravi, Ambulatory respiratory rate detection using ECG and a triaxial accelerometer, Conf Proc IEEE Eng Med Biol Soc.,2013, pp:4058-61. doi: 10.1109/EMBC.2013.6610436.

[34] M. Chan Alexander, S.Nandakumar, F.Nima, N.Ravi, Wireless patch sensor for remote monitoring of heart rate, respiration, activity, and falls, Conf Proc IEEE Eng Med Biol Soc.,2013, pp:6115-8. doi: 0.1109/EMBC.2013.6610948.

[35] W.Qinghui, W.Ye Jin, Lifeng, F.Ansong, Design of Novel Fire Rescue System Based on Wireless Sensor Network, Sensors & Transducers, Vol. 157, Issue 10, October 2013, pp: 168-172, doi: 10.1007/978-3-642-31869-6_35.

[36] W. Aung Aung Phyo, F. Siang Fook, H.Weimin, Jit Biswas, Chi-Chun Hsia, Koujuch Liou, Y. Philip, Lying Posture Classification for Pressure Ulcer Prevention, Journal of Healthcare Engineering · Vol.1, No. 2, 2010. pp: 217–238, doi:10.1260/2040-2295.1.2.217.