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Novel Integrated Sensor Based Sleep Apnea Monitoring and Tracking System Using Soft Computing and Persuasive Technology for Healthcare Support

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Abstract: The Obstructive Sleep Apnea (OSA) is a disease which blocks airway during sleep, leading to serious consequences. There is a need for Polysomnography (PSG), i.e., simultaneous and continuous monitoring of normal and abnormal physiological activity during sleep. The current standard of diagnosis for OSA and PSG requires hospitalization of patient spending one full day at hospital which is an expensive, un-affordable and inconvenient procedure for each and every patient. So, the home monitoring sleep apnea system is needed that would provide an inexpensive and comfortable instant alert system for virtual healthcare solution. This research proposes an embedded system that processes different bio signals, persuasive technology for sleep pattern analysis that then using data mining and soft computing method for inference and diagnosis of OSA. The proposed solution is a low cost, low power, reliable, non-intrusive and non-invasive vital signs monitor that processes and analyses the sleep data pattern and transmit it to the health informatics system using wireless communication medium, e.g., RFID to get retrieval on smart phone and other workstations. The diagnosis of OSA is done by using soft computing approach.

Key words: Embedded systems, fuzzy logic, healthcare, neural network, persuasive-application, polysomnography, sleep apnea, soft computing, virtual health informatics

INTRODUCTION

Sleep apnea is a common sleep disorder that pauses spontaneous breathing during sleep. This pause or absence of breathing can last from 10-20 sec and may occur up to 30 times or more in an hour (NIH, 2013). There are 3 types of sleep apnea:

- Obstructive
- Central
- Mixed

Obstructive Sleep Apnea (OSA) is the most common type of apnea that occurs when soft tissues of a throat relax during sleep and block the airway (NIH, 2013). This blockage whether fully or partially drops oxygen level in blood. If oxygen level reaches to the dangerous level, brain responds by briefly disturbing the sleep and opens the wind pipe that resume normal breathing with gasp or long snoring sound. The phenomenon of sleep apnea is shown in Fig. 1. Normal breathing is shown in Fig. 1a where airway is opened and air flows freely towards lungs as marked by green arrow. Whereas Fig. 1b depicts Obstructive Sleep Apnea (OSA) where airway collapses and blocked as shown with red arrow, the blockage towards lungs is shown by blue arrow. The signs that 1 may suffer from OSA include loud snoring, choking or gasping during sleep, excessive sleepiness, waking up with dry mouth or sore throat, restless or fitful sleep, nocturia, i.e., going to the bathroom frequently during the night and irritability or depression. The other symptoms of sleep apnea are attention deficit, memory loss, morning headache, fatigue, impotence and insomnia.

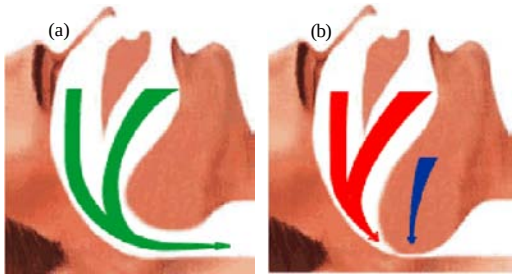

Fig. 1: Sleep apnea: a) Normal breathing where airway is opened and air flows freely towards lungs as shown by green arrow; b) Obstructive Sleep Apnea (OSA) where airway shown with red arrow collapses and blocked the blockage towards lungs is shown by blue arrow

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OSA also release stress hormones that increase the risk of high blood pressure, diabetics and heart diseases (Ayas *et al*., 2003). Moreover, sleep apnea may also change the day time behavior, such as hyperactivity or in-attention. People having OSA therefore may suffer from the car accidents. According to an estimate, 36% of all fatal car accidents are caused from driver drowsiness (Leger, 1994). Poor sleep as a result of OSA can affect memory that deteriorate cognitive functions (Maquet, 2001; Wagner *et al*., 2004; Faubel *et al*., 2009).

Although, OSA is one of the biggest threat towards life but still it is difficult to diagnose in-time promptly. One of the common method for diagnosing is Polysomnography (PSG) that records brain signals, eye movements, heart rate and blood pressure, i.e., simultaneously and continuously monitoring of normal and abnormal physiological activity during sleep (NIH, 2013). PSG often needs specialized sleep lab and patients are admitted for at least over night for diagnosis and tracking of OSA and for a day for post behavior monitoring. It is an expensive, inconvenient procedure which is not affordable and accessible to each and every patient. Thus, home monitoring sleep apnea system is needed to provide inexpensive and comfortable solution.

ANALYTICAL STUDY

Apneas are usually measured during sleep (preferably in all stages of sleep) over a 2 h period. An approximation of the severity of apnea can be calculated by dividing the number of apneas with the number of sleep hours. It gives an Apnea Index (AI). The AI and severity are directly proportional, i.e., the larger the AI, the more severe the apnea, however less AI means non critical.

The decrease in breathing is called hypopnea which is not as severe as apnea is, thus normal breath airflow ranging from 100-70% reveals a hypopnea in between 69-26% of a normal breath. Similar to apneas, the hypopneas are also related with drop in the saturation of oxygen in the blood with a value of 4% or larger and generally happen during sleep. The level of sleep is usually disrupted having hypopneas. The ratio between the number of hypopnea and the number of hours of sleep gives a Hypopnea Index (HI). Combining apneas and hypopneas gives index of severity called Apnea Hypopnea Index (AHI) producing overall severity of sleep apnea including sleep disruptions and de-saturations, i.e., low level presence of oxygen in blood.

Various researchers have presented their hypothetical conclusions. Braley *et al*. (2012) have conducted an experiment for this cause to work on the 2 objectives:

- To assess the dominance and severity of sleep apnea in patients with Multiple Sclerosis (MS) revealed for overnight Polysomnography (PSG)
- To uncover the radiographic and clinical topographies that influence indication of risk for undiagnosed sleep apnea

For this purpose 48 patients with MS from laboratory based PSG, Apnea Hypopnea Index (AHI) and Central Apnea Indices (CAI) data was compared with 2 groups A and B. Group A with 84 sleep laboratory-referred patients without MS and Group B a distinct group of 48 randomly selected referred patients. The data recorded for parameters of age, gender and Body Mass Index (BMI). It is found that:

- Amongst patients with MS, the mean AHI determined larger in comparison to control groups A or B, based on data calculated 2-way ANOVA and multiple linear regression, $p = 0.0011$ and 0.0118, respectively
- Median and mean value of CAI also found larger amongst patients with MS in contrast to Groups A and B, the control groups, based on data calculated Wilcoxon signed rank and multiple linear regression, $p = 0.0064$ and 0.0027, respectively
- A robust difference in ($p = 0.0060$ and 0.0016) and CAI ($p = 0.0215$ and <0.0001) is found among MS patients those with brainstem involvement in comparison to control groups A and B. However, MS patients without brainstem involvement in comparison to control Groups A and B revealed reduced differences in AHI where CAI became significantly similar among groups in contrast

Based on earlier inferential statistics, a predisposition for OSA and accompanying central apnea is suggested among patients with MS mainly patients with brainstem involvement (Braley *et al*., 2012).

DISCUSSION WITH PROPOSED SOLUTION

OSA is an important public health issue with challenges for diagnosis and treatment. It is estimated to occur in about 7% of the population from which >85% remain undiagnosed (Leier, 2013). Current methods of diagnosis and treatment are cumbersome, expensive and inconvenient for patients. Therefore, a new monitoring device of OSA is needed that patient may use in home environment rather than in a sleep lab. Explicit research on apnea has been done and in progress for diagnosis, such as determination of snoring sound, measuring heart and brain waves, etc. These researches have not focused on

all parametric symptoms of OSA. There is a strong need for monitoring and tracking device that can record the data related to human behavior, brain waves signal, heart rate and blood oxygen saturation for diagnosing sleep apnea to generate control signals to activate sensors. This research proposes the technology with persuasive application based on soft computing, fuzzy logic and neural network based intelligent electronic machine to cover this problem. The design is distributed in 3 major areas:

- Embedded system development
- Persuasive application development
- Soft computing based approach for data post processing

EMBEDDED SYSTEM

Proposed system is a smart handheld application. It is an embedded system that processes various bio signals of heart rate, brain waves and blood oxygen saturation (SpO_2) and determines correlation between these signals to increase the reliability. This embedded system consists of Photoplethysmograph (PPG) that produces a continuous and real time measurement. A Photoplethysmogram (PPG) is an optically obtained plethysmogram that is a volumetric measurement of any organ (Shelley and Shelley, 2001). A PPG is often obtained by using a pulse oximeter which illuminates the skin and measures changes in light absorption. PPG signal can also be employed in other vital informations non-invasive measurement, such as the blood sugar and the breath rate.

The signals are sensed through sensors as mentioned in Fig. 2a with red spots. The sensors and are placed in head-band that tracks brain activities via waves (α, β, Δ and θ). The sensors and are placed on chest-belt to determine heart rate. However, sensor is placed in a wrist-band or thumb-band and measures blood oxygen saturation. These signals are further sent via wireless link with RFID or bluetooth based setup linked with bedside unit. Figure 2b shows the setup of bedside unit based on RFID technology coupled with sensors. The signal is than transmitted for post processing as mentioned in Fig. 3. Figure 3 is a mock-up design of suggested embedded system.

Persuasive application: The proposed system also has persuasive application capability that includes self-monitoring and feedback to obtain and maintain healthy sleep habit. It estimates a persons sleep schedule, measures persons day time sleepiness by using Epworth Sleepiness Scale (ESS) and provides summary of feedback

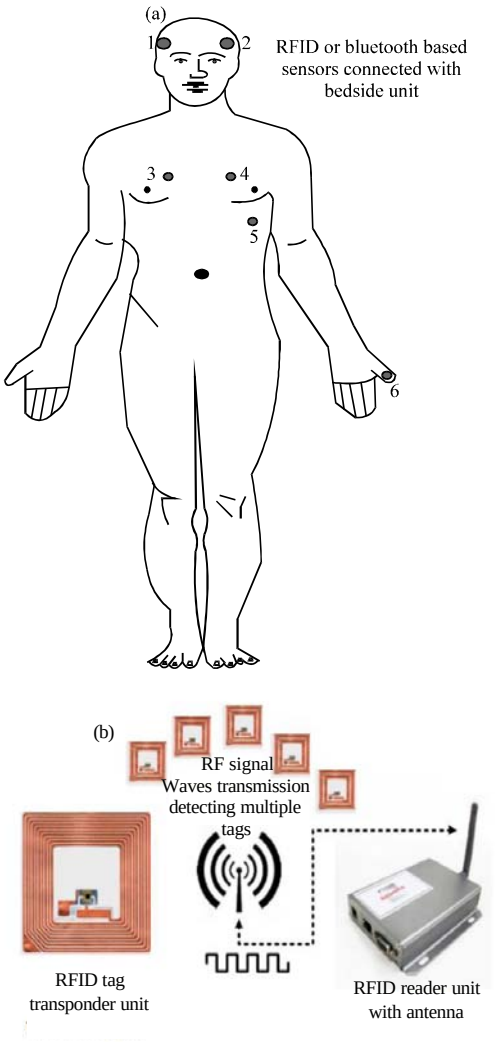

Fig. 2: Brain waves, heart rate and blood oxygen Saturation (SpO_2) determination through sensors. Received signal through sensors then transmitted via wireless link to the bedside unit for post processing: a) Sensors (red spots) are placed on body with RFID tags. Signals are then transmitted to RFID receiver located at bedside unit; b) RF signal waves transmission via RFID setup (Saleem *et al.*, 2012)

to show the current state of patient sleep. This application can also receive user feedback about their past traumatic event, since sleep apnea can be a cause triggered by highly stressful emotion (Drewry, 2012). This feature has never been used in any sleep monitoring technology.

Soft computing: One of the most important features of this application is diagnoses. The soft computing approach with foundation of fuzzy logic, neural networks, support vector machines, evolutionary computation and

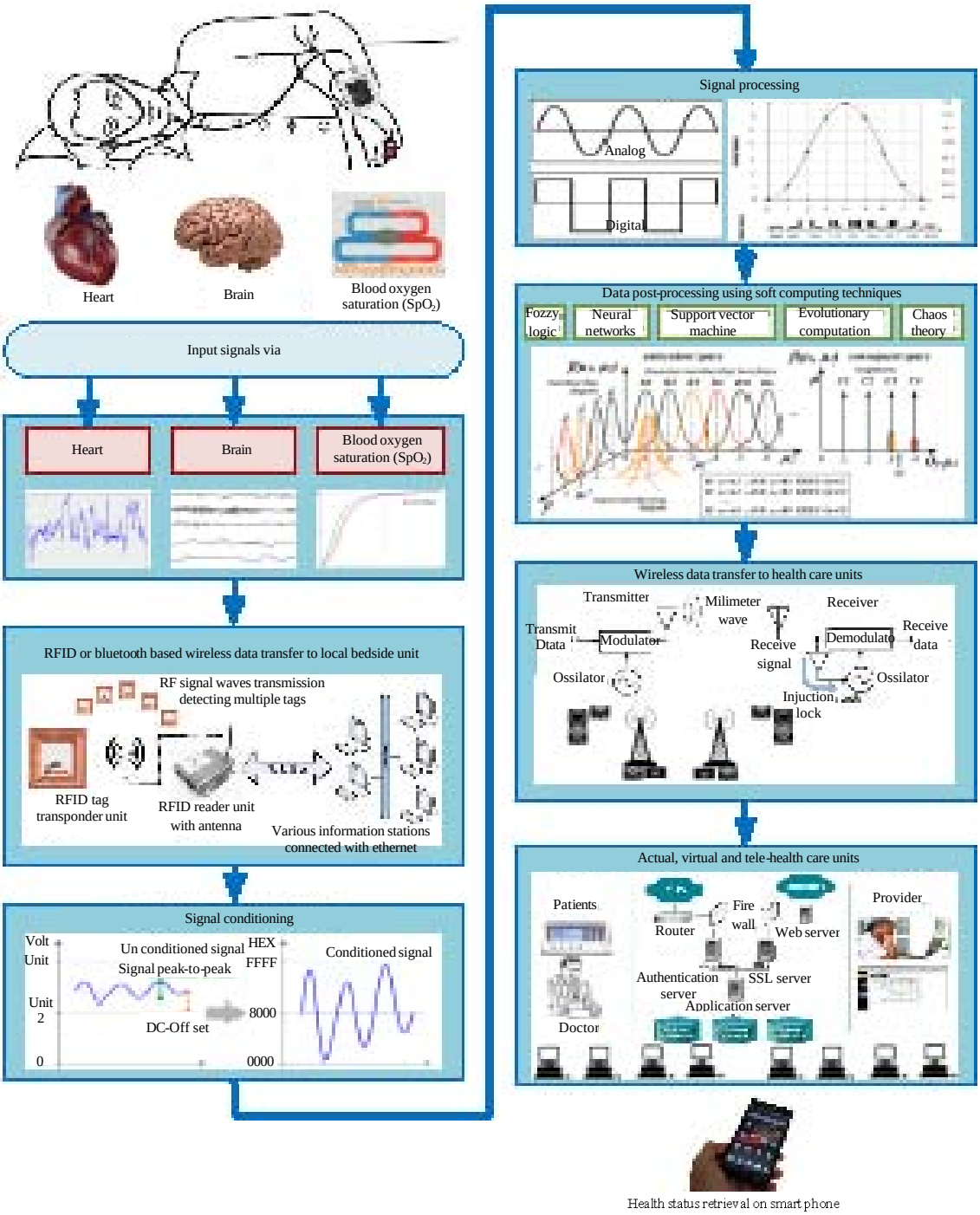

Fig. 3: Mock-up design of proposed embedded system

chaos theory can be helpful for diagnosis of OSA. Inference engine will use data from sensor input, sleep analysis, obesity and traumatic event and apply neural and fuzzy algorithm in order to extract knowledge as output, so that in future, it will help physicians to diagnose OSA. Furthermore, this system records patients age and gender that is a future research requirement to determine consequences based on age-group and gender-group. According to healthcare research and quality effective health care program, age and gender are specific criteria for abnormal breathing (or OSA) and has highest priority of future research (Tufts Evidence-based

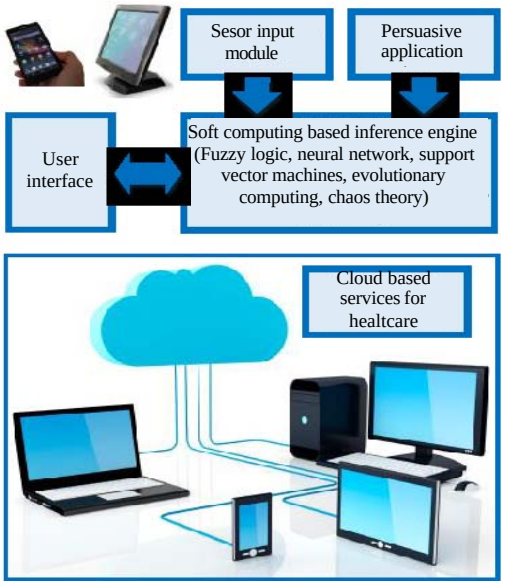

Fig. 4: Architecture of monitoring sleep apnea. Healthcare services available on smart phone

Practice Center, 2012). This system has provision to record patients age and gender for future symptoms of sleep disorder. Figure 4 expresses the methodological architecture of sleep apnea monitoring package. The soft computing based inference engine develops the inference using algorithms of fuzzy logic, neural networks, support vector machine, evolutionary computing and chaos theory taking the data input through input sensor module and persuasive application input module. The user interface provides access and interaction between system and user. User could be doctor, paramedic staff or patient itself (Burney *et al*., 2010).

SIGNIFICANCE

This development is a low cost, low power, reliable, non-intrusive and non-invasive vital signs monitor that processes and analyses the data acquired from sensors, sleep schedule and feedback. The system then transmits data to the users smart phone or workstation by using wireless medium and diagnosis OSA. The main significance of the system is:

- According to the agency for healthcare research and quality effective health care program, there is an intensive need of research on sleep apnea cure (Tufts Evidence-based Practice Center, 2012)
- System can work on age and gender specific criteria for abnormal breathing (or OSA)
- System has routine (or selected) screening feature for sleep apnea determination and control
- This is unique design of diagnostic algorithms that provides diagnoses on portable handheld monitors and smart phones
- The systems main focus is on traumatic event

CONCLUSION

It is well said that health is wealth and if the proper healthcare facilities available on your palm, i.e., on smart phone or smart workstation, then it is precious gift to life. The highly sophisticated soft computing based embedded system proposed is an excellent solution for an OSA which is low cost, low power, reliable, non-intrusive and non-invasive vital signs monitor that processes and analyses the sleep data. This proposed system helps patient to monitor and diagnosis of OSA at home.

REFERENCES

Ayas, N.T., D.P. White, J.E. Manson, M.J. Stampfer, F.E. Speizer, A. Malhotra and F.B. Hu, 2003. A prospective study of sleep duration and coronary heart disease in women. Arch. Intern. Med., 163: 205-209.

Braley, T.J., B.M. Segal and R.D. Chervin, 2012. Sleep-disordered breathing in multiple sclerosis. Neurology, 79: 929-936.

Burney, S.M.A., H. Saleem, N. Mahmood and T.A. Jilani, 2010. Traceability management framework for patient data in healthcare environment. Proceedings of the 3rd IEEE International Conference on Computer Science and Information Technology, Volume 2, July 9-11, 2010, Chengdu, pp: 264-268.

Drewry, D., 2012. Sleep apnea: A new mind/body solution. http://www.wncwoman.com/2012/06/04/sleep-arena-a-new-mindbody-solution/.

Faubel, R., E. Lopez-Garcia, P. Guallar-Castillon, T. Balboa-Castillo, J.L. Gutierrez-Fisac, J.R. Banegas and F. Rodriguez-Artalejo, 2009. Sleep duration and Health-related quality of life among older adults: A Population-based cohort in Spain. Sleep, 32: 1059-1068.

Leger, D., 1994. The cost of Sleep-related accidents: A report for the national commission on sleep disorders research. Sleep, 17: 84-93.

Leier, M., 2013. Sleep apnea detection on babies and children with shoe integrated sensors. Philadelphia, PA., USA. http://nslab.ee.ntu.edu.tw/IPSN13/pdf/1-2.pdf.

Maquet, P., 2001. The role of sleep in learning and memory. Science, 294: 1048-1051.

NIH, 2013. What is sleep apnea? National Heart, Lung and Blood Institute. http://www.nhlbi.nih.gov/health/health-topics/topics/sleepapnea/.

Saleem, H., M.Z.A. Khan and S. Afzal, 2012. Review of various aspects of Radio Frequency IDentification (RFID) technology. IOSR J. Comput. Eng., 8: 01-06.

Shelley, K. and S. Shelley, 2001. Pulse Oximeter Waveform: Photoelectric Plethysmography. In: Clinical Monitoring, Lake, C.L., R.L. Hines and C.D. Blitt (Eds.). W.B. Saunders Co., New York, pp: 420-428.

Tufts Evidence-based Practice Center, 2012. Future research needs for diagnosis of obstructive sleep apnea. AHRQ Publication No.12-EHC031-EF, Tufts Medical Center: Boston, MA.

Wagner, U., S. Gais, H. Haider, R. Verleger and J. Born, 2004. Sleep inspires insight. Nature, 427: 325-355.