Sleep Apnea Detection on Babies and Children with Shoe Integrated Sensors

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ABSTRACT
This work is focusing on patient mobile monitoring solution to increase their mobility, flexibility and measure vital data with minimal patient disturbance. The purpose of the dissertation is to develop embedded system, that is processing different biosignals and finds correlation between those signals to increase the reliability. Acquired data could be divided after processing into different severity groups that need different reaction times depending on the situation. Results will be sent over the wireless link to the smart phone for further diagnosis which is also an alarming device for the end user. There is a trade-off between the amount of signal processing and wireless radio usage. Both need huge amount of energy but finding the best combination between them is one of the goals to choose the correct hardware.

Author of this dissertation has several years of experience with embedded systems and sensor networks, mostly in medical area. He received his master degree in Computer Engineering and has over 10 years professional background in electronics. His goal is to focus on topics that has a potential to use the results in real applications. To extend the knowledge in sensor networks area he has attended several courses abroad and recently had a research stay in Karlsruhe Institute of Technology in Germany. He is currently 3rd year PhD student and expected to graduate in 2014-2015.

1. INTRODUCTION
The need for sleep apnea monitoring devices for babies and children at home environment shows an increasing interest. Currently available devices monitor only baby’s breathing and movements. In addition to that, measuring heart rate and blood oxygen saturation (SpO2) level have huge benefits. In case of Obstructive Sleep Apnea (OSA) breathing movements continue but an obstruction in the windpipe prevents any oxygen reaching the baby’s lung. This is causing sudden SpO2 drop in blood, that is related often to the Sudden Infant Death Syndrome (SIDS). Clinical polysomnograms, which are used for sleep disorder detection, are expensive and require special hospital or sleep disorder centre to monitor patients over-night. Our developed solution includes in addition to breathing movements detection also heart rate, which is calculated from SpO2 signal, and accelerometer used for body posture detection and sleep pattern diagnosis. Those inexpensive at-home self-recording devices can reduce costs by screening out patients who do not need a full sleep study. For babies and children it is also most comfortable way to perform pre-screening. Having diagnostic data from large number of patients there is a better change to perform larger-scale research studies.

2. SLEEP APNEA
The term apnea means absence of spontaneous breathing. It is a common disorder that is estimated to occur in about 7% of the population of which more than 85% remain undiagnosed. SIDS accounts for 22% of all post-neonatal deaths and affect infants with ages 1 month to 1 year. OSA is currently estimated to affect between 1% and 3% of 2- to 8-year old children and is most commonly found in children between 3 to 6 years of age.

Overnight sleep study test includes usually electrical activity of the heart, breathing patterns, SpO2 level, muscle activity and eye movements. For pre-screening purposes collecting all of those signals is not practical. Therefore current research is focusing on most important signals that give immediate feedback about critical conditions.

Market research shows diagnostic sleep apnea devices segment grow CAGR of 15% by 2017 and first devices like sleep mats and body attached sensors are already available.

3. PROPOSED SOLUTION
Proposed solution is focusing on infants from the new-
born up to first year and children between the year 2 to 8 who need to be monitored in case sleep apnea is suspected. Based on the research most important parameters that are needed for continuous monitoring of vital signs are heart rate, SpO2 level, respiration, body posture and activity. Since the solution is mostly used during the sleep time it should have minimal effect on disturbing normal sleep. Therefore it is chosen to integrate sensing module of the system into the shoe that is carried by the patient during the sleep. Similar solution is proposed by [1] but without respiration signal measurement which is mandatory for detecting sleep apnea.

Figure 1: Portable sleep apnea monitoring system block level description

Figure 1 describes proposed solution’s architectural design. Sensing device with sensor and signal processing, and smartphone with user interface divide it into two main parts. System consists one or more PPG sensors and one accelerometer. Because PPG is the basis for three extracted signals it has to be reliable and minimize possible artefacts. Therefore it needs additional research and practical testing how stable is the signal during long time monitoring. Best sensor location on foot has to be found during the sleep tests.

Acquired sensors need cleaning with low-pass and high-pass filters and DC component removal without removing useful information from the base signal. Therefore some part of filtering has to be done after SpO2 and respiration calculations. In case of artefacts, measurements will be compared with the acceleration signal and unusable parts of the signal will be disregarded.

After signal preprocessing different algorithms will be used to detect sleep apnea. Frequency of breathing, SpO2 level and heart rate are used for detecting sleep apnea. Second PPG sensor would give an advantage to use it as a reference signal in case readings from one sensors are out of limits. Accelerometer based body posture and sleep pattern detection could give an additional information whether sleep apnea is correctly detected.

Wireless radio is used to transmit the results to the smartphone which has to be in range to receive alarms. As the sensing device needs to operate at least one sleep cycle and perform continuously initial calculations with wireless data transfer it needs further research what is the minimum amount of processing it needs to perform. The frequency of the radio usage depends on the amount of signal processing and should be changed dynamically based on the importance of the results. Determining correct severity depends on the reliability of the input signals needs extended practical testing.

Smartphone usage eliminates the need to develop extra hardware for deep data analysis and storage. In case there is a need for extended monitoring in sleep clinic, smartphone is acting as a gateway to transfer analysed results to the medical personnel.

4. CONCLUSIONS

Proposed solution helps to decrease cost and increase accessibility to diagnostic monitoring for sleep studies. For the neonates and children the most comfortable way to perform pre-screening is to evaluate it in the natural home situation. Our proposed solution is designed to include all the most important signals for pre-screening and give early warning about possible life threatening situations using low energy wireless communication with smart phones.

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5. REFERENCES