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Enhancement of sensor mesh functionality with application on sleep tracking

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Topic:	**Enhancement of sensor mesh functionality with application on sleep tracking**
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Title: **Enhancement of Sensor Mesh Functionality with Application on Sleep Tracking**

Description:

The focus of this project is enhancement of functionality, reliability and sensor accuracy of an intelligent bed that monitors human sleep. The scope of the project includes the implementation of an application layer protocol and network communication between the embedded system in the bed and remote server. Furthermore, the implementation possibilities of data preprocessing, filtering, and automatic sleep analysis are explored and tested. The system is tested and evaluated in the Ubiquitous Computing Laboratory at the Hochschule Konstanz University of Applied Sciences.

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Contents

1 Introduction

To help readers get better acquainted with the topic, introduction is divided into four sections. First section covers general motivation and relevance of the project. Next section describes state of technology, market and consumer trends at the time this thesis was published. The following section lays out project goals and defines the scope they will be tackled on while in the last section, project structure is outlined so that readers can easily navigate through this thesis body.

1.1 Motivation

Sleep is seemingly a trivial thing - from the moment that they are born, all humans have a need to sleep. It is a natural function in the same way breathing and other vital body functions are. Having slept for adequate time and with good quality tends to make people feel good and have more energy performing their daily tasks. When a person did not sleep well or did not sleep enough it will usually negatively reflect both on their body and their behaviour. National Sleep Foundation along with multi-disciplinary expert panel recommends sleep time for each age group ranging from 14 to 17 hours daily for newborns to between 7 and 8 hours for older adults[1]. Sleep deprivation effects motor and cognitive abilities as well as mood but these effects can also occur in cases of bad sleep quality regardless of the sleep duration[2]. That same sleep quality is influenced by many factors ranging from physical ones such as sleeping environment and position to subjective ones such as emotional state and dreams. As clear separation of these factors is rarely possible, most of the researches relied on the isolation of influences comparing results between large control and influenced groups. Sleep quality is then usually determined by questionnaires and data analysis which resulted in quantitative results such as Pittsburgh Sleep Quality Index[3].

A more technical way of determining the sleep quality is active sleep monitoring and continuous sleep tracking. This method involves continuous or periodical measurement of physical parameters. Some electrophysiological measurements that can be done to precisely parametrize sleep are Electroencephalography (EEG), Electromyography (EMG) and Electrooculography (EOG). Drawback of using these methods is requirement of complex equipment, knowledge to evaluate the results and controlled environment which is why these measurements are usually done only for clinical or research purposes. But simple sleep monitoring can be done using much simpler processes - with heart rate, body movement and position tracking. Unlike before mentioned measurements these can be done unobtrusively and in home environment. Improving the process and accuracy of these methods and improving correlation of collected results to the real sleep parameters may lead to much easier diagnosis of sleep disorders. Furthermore, availability and accessibility of this technology will encourage larger number of people to monitor their sleep performance which may lead to better mood, efficiency of executing

daily tasks and sport results. This thesis will primarily focus on finding a non-obtrusive way to track both sleep time and quality with proposal of technology and measuring methods

1.2 Technology and current consumer market trends

In the recent years, the market for sleep and fitness tracking devices has been expanding with the support of almost all major smartphone manufacturers. Some new brands specializing in the making of such devices have also emerged and have been steadily gaining the market share. Most of the devices that are currently used for consumer sleep tracking are actually multifunctional devices such as smart watches, armbands and rings. Beside sleep, they usually track physical activity, pulse and show time or provide some other information. Smart watches are additionally customizable as they usually allow for installation of third-party[1] applications. This versatility makes such a device very attractive to the customer regardless of sleep tracking and monitoring quality. To paint a better picture, in 2014 Dr. C. Winter compared a few of the most popular sleep tracking armbands to the polysomnogram[4]. His results are showing that most of the devices, regardless of their cost, were able to distinguish between awakeness and sleep which allowed them to measure the time spent sleeping. Unfortunately, they were not able to separate REM, N1, N2 and N3 sleep phases or estimate the time spent dreaming. Some devices provided estimate if a person was in a deep or light sleep but the results were mostly inaccurate. In late 2016 J. Yoon tested newer iteration of the consumer devices and the results(1.1) show improvement of the deep or light sleep phase detection but devices are still not accurate enough to guess the real sleep phase with an acceptable degree of certainty[5].

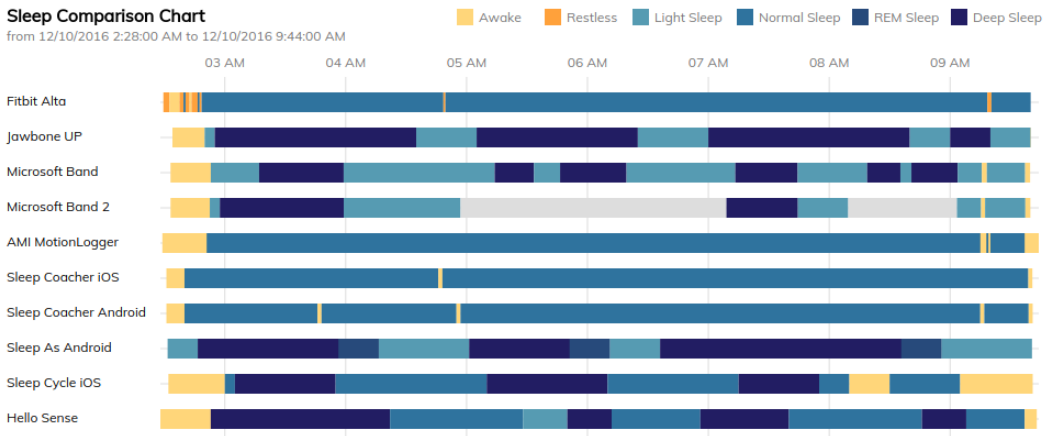

Figure 1.1: Sleep detection comparison between consumer devices

The reason for inaccuracy of consumer on-body sleep tracking devices is the underlying technology. Microelectromechanical systems (MEMS) sensors are used for movement tracking and simple photo sensors are used for Photoplethysmography (PPG) which gives an estimate of pulse frequency. Additionally some devices use microphone to detect apnea. Most of the devices are designed in such a way that they are non-obtrusive, small, easy to use and nice looking. This means that batteries powering sleep monitoring

[1]Not provided by the original manufacturer

devices must be small and device usage should be minimized to maximize the battery life. This is achieved through the use of low power microcontrollers, through updating movement sensor data in an interrupt routine which wakes up the microprocessor and through minimizing the number of readings done by the PPG sensor. This, of course results with the inability of devices to categorize sleep phases with acceptable certainty and most manufacturers categorize sleep as just light or deep.

Contactless consumer devices that are specialized for sleep tracking and monitoring are newest to the market. They are using sound to detect breathing and body movement through the night. Depending on the product they can also measure light for easier start of sleep detection. Since smartphones also have microphones and light sensors, multiple applications which analyse the sleep are present on the market. This method is favorable in some cases because it eliminates the need for a device touching the subject. But what it has in practicality, this method lacks in accuracy as sound and light sensors are easily disturbed by the events present around the sleep environment. This method has also a problem of distinguishing multiple sound sources eg. multiple people sleeping in the same room.

1.3 A poll on perceived influence of sleep and usage of sleep tracking devices

Young adults are an age group with the most early adopters of new technologies. In general and due to the lifestyle, they are likely to have suffered from short term or long term sleep deprivation. Getting the best sleep quality with the minimal time spent sleeping can be a beneficial factor to the outcome of the exams and handling of stressful tasks. A poll was conducted between peer students at the University of Zagreb with a goal to analyse the perceived influence of sleep and usage of sleep tracking devices in that group. It should be taken into consideration that the total number of poll participants is *12345125* and they are localized both geographically and by social group. Therefore the results will be compared to other polls and researches which include more data in both quantity and diversity. In case that no data on the subject was found, a result from this poll will be used but this will be noted in the text.

Conducted poll results show that majority of students are on average getting ***7 hours*** of sleep daily which is quite close to the ***result*** determined by the NSF[1]. For relative majority of ***PERCENT*** this amount of sleep is adequate to their needs. To get a perception what influences their sleep, they were asked if sleep duration, sleep environment[2] and external conditions[3] influence their sleep quality. The results show that much bigger percent of participants perceives that sleeping environment and external conditions impact the quality of sleep compared to pure duration of the sleep. A vast majority of poll participants (***PERCENT***) indicated that they would like to have an insight into their sleep but most of the participants indicated that they are not certain if that data would actually improve their sleep quality.

PERCENT of participants are familiar with sleep tracking devices and only ***PERCENT*** have used a non obtrusive sleep tracking device. Out of all poll participants, only one has tested its quality of sleep using clinical methods such as EEG, EMG or

[2]eg. bed quality, sleeping garments
[3]eg. temperature, humidity, pressure, noise levels, moon phases

EOG. As widely available sleep trackers are still quite new to the market, all of the participants have been in a possession of the device for less then a year. Also, all of the participants that own a sleep tracking device indicate that they check their sleep quality on a weekly basic or more frequently and that data received from the sleep tracking devices has helped them improve their sleep quality. A majority of ***PERCENT*** of that group indicates that they would like to have an even more precise and detailed device to track their sleep.

1.4 Goal and scope

<Describe product> <Describe how the product will be used>

1.5 Project outline

to do

2 Hardware

2.1 Circuit design and development

2.1.1 PCB design

2.1.2 Prototype production

2.1.3 First revision

2.1.4 Second revision

2.2 Microcontroller and peripheral devices

2.3 Connectors

2.3.1 FSR sensor connectors

2.3.2 Internal bus connectors

2.3.3 Cortex debug port

3 Embedded

4 Software

5 Usage and measurements

6 Results

7 Conclusion

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Symbols, Units and Abbreviations

EEG Electroencephalography

EOG Electrooculography

EMG Electromyography

MEMS Microelectromechanical systems

PPG Photoplethysmography

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Enhancement of sensor mesh functionality with application on sleep tracking

Abstract

The focus of this project is enhancement of functionality, reliability and sensor accuracy of an intelligent bed that monitors human sleep. The scope of the project includes the implementation of an application layer protocol and network communication between the embedded system in the bed and remote server. Furthermore, the implementation possibilities of data preprocessing, filtering, and automatic sleep analysis are explored and tested. The system is tested and evaluated in the Ubiquitous Computing Laboratory at the Hochschule Konstanz University of Applied Sciences.

Keywords: sleep tracking, embedded systems, sensor meshes, sleep analysis

Primjena senzorskih mreža na praćenje ljudskog sna

Sažetak

Tema projekta je unaprjeđenje funkcionalnosti, pouzdanosti i preciznosti rada inteligentnog kreveta koji prati ljudski san. U sklopu projekta implementira se aplikacijski sloj te ostvaruje mrežna komunikacija između ugradbenog sustava u krevetu i udaljenog računalnog servera. Nadalje, rad istražuje i testira implementaciju preprocesiranja podataka, izrade podatkovnih filtera i automatske obrade i analize podataka o snu. Sustav se testira i evaluira u Laboratoriju za sveprisutno računarstvo pri Hochschule Konstanz University of Applied Sciences.

Ključne riječi: praćenje sna, ugradbeni sustavi, mreže senzora, analiza sna