UNIVERSITI TEKNIKAL MALAYSIA MELAKA

BREATHING PHASE AND BODY MOVEMENT DETECTION FROM 9 DOF ACCELERATION DATA FOR SLEEP MONITORING

This report is submitted in accordance with the requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor of Computer Engineering Technology (Computer Systems) with Honours

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DECLARATION

I hereby, declared this report entitled "**Breathing Phase and Body Movement Detection from 9 DOF Acceleration Data for Sleep Monitoring**" is the results of my own research except as cited in references.

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APPOROVAL

This report is submitted to the Faculty of Engineering Technology (FTK) of Universiti Teknikal Malaysia Melaka (UTeM) as a partial fulfilment of the requirements for the Bachelor Degree of Engineering Technology Computer Engineering Technology (Computer System) with Honours. The member of the supervisory is as follow:

……………………………….

(Project Supervisor)

ABSTRAK

Tidur yang baik dan cukup penting untuk kekal sihat dan bertenaga. Pemantauan tidur membantu mengesan sebarang jenis gangguan tidur terutamanya apabila seseorang merasa keletihan setiap pagi ketika mereka bangun. Untuk memantau aktiviti nafas tidur serta pergerakan badan, projek ini mencadangkan kaedah alternatif dan bukannya menggunakan alat pemantauan tidur mewah yang mahal. Melalui telefon bimbit MATLAB, data dikumpulkan untuk dianalisis oleh MATLAB di PC. Data 9 DOF termasuk paksi x, paksi y dan paksi z pecutan data, data orientasi dan data magnetik dikumpulkan melalui telefon pintar Android dengan sensor tertanam. Data mentah yang dikumpulkan akan menjalani teknik penapisan untuk menapis data yang tidak berkenaan dan mengeluarkan data yang diperlukan. Teknik menentukan puncak akan digunakan untuk menghitung kiraan nafas data yang ditapis. Eksperimen direka untuk menentukan prestasi kaedah ini. Eksperimen 1 memberikan purata 90.84% manakala percubaan 2 memberikan ketepatan purata 95.69%.

ABSTRACT

Getting good and enough sleep is important to stay healthy and energetic. Sleep monitoring is helpful to detect any type of sleep distortion especially when a person feel fatigue every single morning when they are wake up. In order to monitor sleeping breath activity as well as body movement, this project propose an alternative method instead of using high-end sleeping monitoring device which cost a lot. Through MATLAB mobile, the data was collected to be analyze by MATLAB in PC. The 9 DOF data including x-axis, y-axis and z-axis of acceleration data, orientation data and magnetic data was collected through Android smartphone device with embedded sensors. The raw data collected will then undergoes a filtering technique to filter noise data and extract data needed. Peak determine technique will then applied to count the breath count of the filtered data. Experiments was then designed to determine the performance of this method. Experiment 1 give an average of 90.84% while experiment 2 give an average accuracy of 95.69%.

DEDICATION

Dedicated to my beloved parents who supported me all the time, my supervisor who guided me, and all my friends who always by my side

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TABLE OF CONTENTS

APPENDICES

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURES

ECG	Electroencephalogram
EEG	Electrocardiogram
DOF	Degree of Freedom
HMM	Hidden Markov Model
SSRD	Sleep related respiratory disturbances
MATLAB	Matrix Laboratory
HRV	Heartrate variability
Wi-Fi	Wireless Fidelity
REM	Rapid eye movement
NREM	Non-rapid eye movement
PSG	Polysomnography
MEMS	Micro Electro Mechanical System
.mat	Microsoft Access Table shortcut

Chapter 1

INTRODUCTION

1.0 Introduction

This chapter basically discussed about research background, problem statement, research objective, scope of study, and thesis organization about this project.

1.1 Research background

Getting good and enough sleep is important to stay healthy and energetic. Sleep monitoring is helpful to detect any type of sleep distortion especially when a person feel fatigue every single morning when they are wake up.

Sleeping is essential for a person to keep healthy and energetic. Therefore, sleeping monitoring system is popular among consumer in the market especially to the elderly of patient. Recent advanced research of wearable device and smartphone sensing had led to home use sleep monitoring for the consumer in the market. (Huang et al. 2015)

There are a few parameters that can be considered to use in sleep monitoring purposes such as body temperature, heart rate, EEG(Electroencephalogram), ECG(electrocardiogram), rapid eye movement, breathing phase and body flipping.(Suzuki et al. 2009)

According to (Hoque et al. 2010), Sleep monitoring is important for people because when one is in adequate and irregular sleep, he/she will be often related to serious diseases such as depression and diabetes. In many cases, it is necessary to monitor the body positions and movements made while sleeping because of their relationships to particular diseases (i.e., sleep apnea and restless legs syndrome). Analyzing movements during sleep also helps in determining sleep quality and irregular sleeping patterns.

Wearable embedded system technology being popular since body-wearable sensor networks is used for remote health and activity monitoring. Therefore, body-wearable sensor networks enable a personalized approach to health and wellness. Such networks will provide promising applications in medical systems to enhance people's quality of life. (Vahdatpour et al. 2012)

1.2 Problem statement

In these years, many people living through stressful lifestyle. Most of the citizen suffering through sleeping disorder caused by mental stress, inconsistence work shift, and irregular lifestyle. But, it is impossible for a person to determine whether his or her sleeping quality since he/she is undergoes sleeping process. So, sleeping monitoring devices are necessary for a person to determine his/her sleeping quality or in other word to determine his/her sleeping data such as breathing phase or body movement. (Pradella 1992)

Therefore, with the help of technology, sleeping monitoring device was invented and born in the market. Unfortunately, for higher accuracy to determine sleeping quality, we need high end device which may cause consumer thousands of US dollars (refer to Figure 1.1). Then, in these few years, fitness tracker with accelerometer and heart-rate monitor sensor (refer to Figure 1.2) is born to track user's healthy level. Since it cost less compared to high end device, developers used it sensors to determine user's sleeping data as well, but accuracy of the data isn't that promising compare to the high end device. Therefore, an idea to design a system which is low cost but at the same time giving the accurate sleeping data comes up and this project is carried out to do so.(Nam et al. 2016)

Figure 1.1: High end sleeping monitoring device

Figure 1.2: Fitness trackers in the market

1.3 Research objective

This project was proposed to collect and analyse the breathing phase of user during sleeping by utilizing the available sensors in android smartphone. This project need to achieve the following objectives listed.

1.3.1 Main Objective:

- To measure the parameter of user's breathing phase and body movement through a 9 DOF device (android smartphone)
- To analyse the data collected from 9DOF detector using MATLAB

1.4 Scope of Study

The scope of this project is to develop an algorithm to analyse breathing phase and body movement using 9 DOF acceleration data for sleep monitoring. The data collected from accelerometer sensor, magnetometer and gyroscope in smartphone device is send to PC to be analysed. Parameter received would be the accelerometer sensor data which will then interpreted and analysed. Then, MATLAB software is used to analyse data and MATLAB language is used as the developing language.

This project is only to provide user who want to monitor their sleeping patterns and breathing phase for home use in low cost.

1.5 Thesis organization

In order to accomplish this research, 5 chapters were included which are Introduction, Literature Review, Methodology, Result and Discussion, and Conclusion and Recommendation of the project.

Chapter 1 introduce the basic idea of the project. It includes how the project came out with, objectives and problem statement of the project, and the scope of the project study.

Chapter 2 is literature review of other similar research that are related to his project and equipment/sensors that utilised during the project proceed. The other researches were studied to have a better understanding before project is carried out.

Chapter 3 is an explanation on the methodology of the project. This section consists of all method that are used in this project including the flow chart of the project, MATLAB software, algorithm used, coding and etc.

Chapter 4 focus on the results obtained from experimental activities performed by user and analysis of the data that tabulated in graph, table and figure form. The results will then be discussed in this chapter with related factor.

Chapter 5 highlights outcomes of the projects by concluding all the findings relevant. Recommendations will then be described to enhance and optimizing future works.

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

This chapter discuss on literature review of the previous research that are done by previous researcher that was related to this project. Literature review that will be discussed in this chapter is about some available sensor that will be used in sleeping monitoring system in smartphone device. Every fundamental used in this project will be described in detail in this chapter. Besides, any other terms or devices used in this project will be explained from resources of other thesis, journal, and websites that containing related information.

2.1 Breathing phase during sleeping

Generally speaking, sleep is a kind of brain activity and its purpose is to recover from brain fatigue. Thus, sleep state is measured mainly by EEG, and is classified into several stages. Sleep state is categorized roughly into REM (rapid-eye movement) sleep and NREM (Non-rapid eye movement) sleep. NREM sleep is then divided into 4 stages. Stages 1 and 2 are shallow sleep while stages 3 and 4 of NREM sleep are so called deep sleep. These stages area decided by a sleep specialist using PSG data (Moser et al. 2007) and their changes is shown in a graph called a hypnogram.

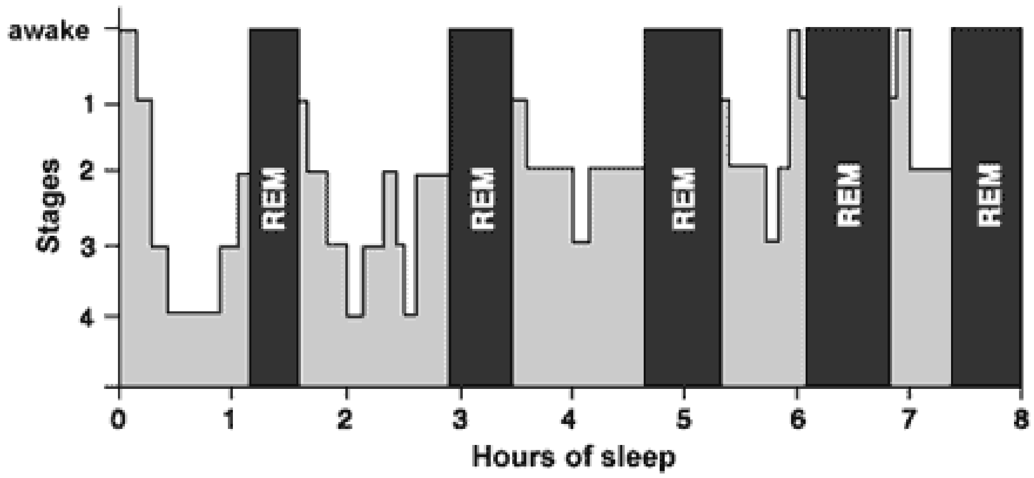

Figure 2.1: Sleep hypnogram

According to (Pradella 1992), a normal adult's breathing frequency is highly reproducible within an individual ranging from 8 to 25 during sleep. This variable is rarely reported in studies of adults with various sleep related respiratory disturbances (SRRD).

Normal people breathe more rapidly and shallowly in all stages of sleep than during wakefulness, the lowest mean tidal volume occurring in REM sleep, when the depth of breathing was highly variable. These changes resulted in lower expired volumes in non-REM sleep than during wakefulness, with a further appreciable reduction in ventilation during REM sleep, which was associated with a parallel reduction in inspiratory drive (VT/Ti). (Douglas et al. 1982; Yuan et al. 2013)

2.2 Previous related research

Several researches around the world have been carried out to develop sleep monitoring system. For example, body/wrist motion has been used for wake/sleep identification. The amount of activity measured from acceleration sensors is often used for monitoring wake/sleep rhythms (Sadeh, 1989), but unfortunately the sleep stages still cannot be determined from the data.

2.2.1 Development of a Sleep Monitoring System with Wearable Vital Sensor for Home Use (Suzuki et al. 2009)

Recently, the focus of researchers have been moved to measure heart/pulse rate and analysing its variability: HRV (Watanabe, 2004, Michimori, 2003 and Wakuda, 2007). The sleep stages will be calculated and analysed from HRV if the indices of HRV are properly mapped for sleep stages.

But there were limitations in this approach, one was that body/wrist motion often affects the heart/pulse sensing and the HRV values miscalculated. Another one was the level of autonomic nervous activity differs accordingly based on age, sex and body/mental condition. For example, young mans' autonomic nervous system generally much more active compare to that old. Therefore, a research in 2009 carried out by Takuji Suzuki and his colleagues overcome these limitation by using sensor to measures both pulse wave interval and wrist motion. Therefore, the wrist motion data not only being used in detecting amount of activity, but also to detect the error occurred in HRV data calculation. For another problem, the research employed a statistical method to decide sleep stages. They broke down the sleep stage data into several groups between 90-120minutes since period of sleeping time repeats about every 90 minutes. In this approach, the threshold to divide sleep stages is much flexible with the data set. The experiments accuracy was up to about 73.5% after dozens of comparison experiments was performed. (Suzuki et al. 2009)

However, this approach need a newly designed wearable physiological sensor and PC software. Although it was light-weight and easy-to-use compare to sleep monitoring system used in hospital. Yet, it still cost another device to carry out the data collection.

2.2.2 An Smartphone-based Algorithm to Measure and Model Quantity of Sleep (Gautam et al. 2015)

A group of scientists from New Delhi, India carried out a research in 2015 to measure and model quantity of sleep using an smartphone-based algorithm. They used three different approaches to classify raw acceleration data into two states- Sleep and Wake.

First approach, they took an equation from Kushida's algorithm to process accelerometer data which was later known as Kushida's equation.

```
Data: acurr
Result: State
acurr <- raw accelerometer series ;
amod <- modified accelerometer series ;
len <- length of acurr ;
i <- 1 ;
read current;
while i <= len do
    if (i > 4) and (i < len $ 4) then
        amod(i) =
        0.04 *acurr(i $ 4) + 0.04 *acurr(i $ 3)
        +0.20 *acurr(i $ 2) + 0.20 *acurr(i $ 1) +
        2 *acurr(i) +0.20 *acurr(i + 1) + 0.04 *
        acurr(i + 2) + 0.20 *acurr(i + 3)
        +0.20 *acurr(i + 4) ;
    else
         amod(i) = acurr(i) ;
    end
    i <- i + 1;
end
thres <-  Selected threshold ;
j <- 1;
State <-  Sleep/wake state map;
while j <=  len
   do
      if amod(j) < thres then
      State(j) = 1
    else
      State(j)=2
    end
       j<- j + 1
end
return State
```

Algorithm 1: Kushida’s Equation-based Approach

Second approach involves a simple statistical technique in which data is first processed by discarding the noisy data, in the form of high amplitude. Then, the data is normalized to amplitude range between zero to one. If the samples is greater than the threshold, the window is classified and Wake, otherwise sleep.

```
Data: normalizeddata
Result: State
normalizeddata <- data after noise removal;
```

```
normalization to range 0 to 1 ;
len <-  length of normalizeddata;
num <- number of samples in 4 min window;
j<- 1;
while j <= len - num
do
 i <- 1;
 k <-1;
 thres <-  (mean + stddev)/2;
       while i <= num do
            if acurr(i) < thres then
                count = count + 1
            end
            i<- i + 1 ;
        end
        if count < 0.4  *num then
            State(k) = 1
        else
        end
        State(k) = 2
        count 1;
        i<- 1;
        j<- j+num;
       k<- k+1;
end
return State
```

Algorithm 2: Statistical Method-based Approach

Third approach involve the detection of Sleep and Wake using HMM (Hidden Markov Model) training. The model is trained using the HMM Viterbi algorithm. The algorithm will observe sequence and the sequence of state correspond to the observation as input and gives emission and transition probabilities as output.

```
Data: acurr
Result: State
amod<- modified accelerometer series ;
len <- length of acurr;
I <- 1;
zeodata <- Extracted data from Zeo sensor ;
data <- after noise removal and normalization;
datafin <- downsampled to match the rate of Zeo sensor;
(State)=runHMM(datafin, datagrp,zeogrp). Calculates
state map
return State
```

Algorithm 3: HMM Training-based Approach

```
Data: datafin,datagrp,zeogrp
Result: State
dataquant <-  Quantize datafin;
datagrp<- m by n matrix;
m <- no. of days n length of accelerometer data;
zeogrp <-  m by n matrix;
m <-no. of days n length of Zeo data;
(trans,emiss) = hmmestimate(datagrp, zeogrp) .
Maximum likelihood estimate
(State) = hmmviterbi(seq, trans, emiss) . Calculates
state map
return State
```

Algorithm 4: *runHMM()* function used in HMM Training-based Approach

They made some comparison between these three approaches and the accuracy of these three approaches was compared after all three algorithm was compared to Zeo sensor which use EEG to measure sleep data.

Table 2.1: Comparison of the three approaches in terms of accuracy in classifying Sleep and Wake states (source:(Gautam et al. 2015))

Approaches	Advantages	Disadvantages	Accuracy
Kushida's equation	Computationally least expensive among three approaches	Less accurate	Max : 65% Avg : 59%
Statistical Method	Uses statistically sound method	Required more amount of data compare to Kushida's equation	Max : 74% Avg : 68%
HMM training	Result of previous state will influence the state recognition result of the next state	Involve training, therefore requires more resources in term of sensor and computation	Max : 84% Avg : 79%

2.2.3 Sleeping Monitoring Based On a Tri-Axial Accelerometer and a Pressure Sensor (Nam et al. 2016)