SOFTWARE ENGINEERING

Sleep Quality Assessment

.....How well do you sleep???

Report 1

Cagdas Karatas	cagdas@cac.rutgers.edu
Chenyun Lan	lan.chenyun@hotmail.com
Jianjun Zhu	zjjjun1991@hotmail.com
Mridula Krishnapur	mridu89@gmail.com
Yangkai Zhou	zhouyangkai1991@hotmail.com
Zeya Zhang	tooth6612@gmail.com

Project Website: here

TABLE OF CONTENTS

CONTRIBUTION BREAKDOWN

All members contributed equally for this report.

1. PROBLEM STATEMENT

1.1 Introduction

"Healthy brains depend on healthy sleep; Healthy bodies depend on healthy sleep"

These are two of the Golden Sleep Principles from the website of World Sleep Day Org. The World Sleep Day is an annual event organized by the World Sleep Day Committee of the World Association of Sleep Medicine (WASM) since 2008. It is aimed to celebrate the benefits of good and healthy sleep and to draw society attention to the burden of sleep problems and their medicine, education and social aspects; to promote sleep disorders prevention and management.Through the World Sleep Day the WASM tries to raise awareness of sleep disorders and their better understanding and preventability, and to reduce the burden of sleep problems on society that constitute a global epidemic and threaten health and quality of life for as much as 45% of the world's population.

Good sleep can eliminate fatigue and resume physical strength, protect the brain, restore energy, enhance immunity, anti-aging and promote longevity. However, many people are suffering the insomnia. Insomnia has become a serious disease in the last decade, 45% of the world's population are suffering this disease. Insomnia is the inability to sleep or inability to stay asleep, leading to lack of sleep. It is also known as initiating and maintaining sleep disorders, for a variety of causes difficulty falling asleep, sleep depth or frequency through the short, early awakening, and inadequate or poor quality sleep. Insomnia is a common disease. It often makes patients feel great pain and psychological burden. Abusing drugs will damage patients' bodies and hurt many other aspects. And the social activities will be negatively affected during daytime. These show that a high quality of sleep is very important to everybody.

1.2 Background

A good sleep can be quantified and detected based on ECG and heartbeats.When people have a good sleep, their recorded heartbeats are stable without abnormal pulses. Scientifically there are five stages of sleep:

Stage 1: Beginning of sleep, relatively light stage of sleep, can be considered as a transition period between awake and sleep. It lasts about 5 ~ 10 mins.

Stage 2: It lasts about 20 mins, heart rate begins to decrease.

Stage 3: Transition period between light sleep to very deep sleep.

Stage 4: Stage 4 is a deep sleep that lasts approximately 30 mins, bedwetting and sleepwalking usually happen at the end of stage 4 sleep.

Stage 5: Most dreaming occurs during this stage, known as Rapid Eye Movement(REM) sleep. During this stage, body system become more active, and heart rate is supposed to rise up. On an average, we enter the REM stage approximately 90 mins after falling asleep. The lasting time of REM stage might get longer with each sleep cycle, up to an hour as sleep progresses.

There exists a clear relationship between the heart rate while asleep VS. awake. Dr. K. Krrauchi, in a study reported in “Neuropsychopharmacology” (2001) detected an average drop from 64 to 52 beats per minute from lights off till you reach light, continuous sleep. Paper concludes that subjects’ heart rates vary between sleep and awake. The low frequency power as well as the high frequency power was lower when the subjects were asleep. There is a relationship between the variation of heart rate and a specific sleep stage. Basically, the larger variation usually goes with the REM sleep. Difference of heart rate variation between REM sleep and Non-REM sleep may be used to distinguish the sleep stages. On the other hand, in the frequency domain, one study has showed that compared to Non-REM sleep, low frequency band power has decreased and low frequency (LF) to (HF) ratio has significantly increased during REM sleep.

Based on the scientific findings as cited above, we aim to create a model to tell apart sleep stage and awake stage in a whole sleep cycle. We intend to use MOTOACTV which gives us a log of the heart rate of a person to identify the stages of sleep in the customer and make use of this data to diagnose a possible sleep disorder, report the quality of sleep and finally suggest improvement in sleeping habits.

1.3 Project Overview

Sleep Quality Assessment as a product must provide the following experience to the user:

1. The user must be create a log in with SQA's interface
2. The user then puts in important contact information like phone number, time he usually sleeps etc
3. The user receives a text at his designated sleep time reminding him to wear MOTOACTV before he sleeps
4. The user presses start button on MOTOACTV when he/she lies down
5. When the user wakes up in the morning, he/she presses stop
6. The data is logged and analyzed at the server and a report of the night's sleep is emailed to the user
7. The user receives a report with suggestions to improve sleep quality and possible anomalies
8. The same process repeats as long as the user wishes to.

1.4 Glossary of Key Terms

EEG – EEG is the recording of electrical activity along the scalp. EEG measures voltage fluctuations resulting from ionic current flows within the neurons of the brain. third clinical use of EEG is for studies of sleep and distinguishing sleep stages.

ECG – ECG is an interpretation of the electrical activity of the heart over a period of time, as detected by electrodes attached to the surface of the skin and recorded by a device external to the body.

Resting Heart Rate – The heart rate, measured in beats per minute (bpm), measured when the subject is awake, but has not performed physical activity. The resting heart rate is an indicator of general health. It is also a reference to compare the heart rate between sleeping and awake.

Maximum Heart Rate – The highest rate of heart beats per minute that is achieved during sleeping.

Minimum Heart Rate – The lowest rate of heart beats per minute that is achieved during sleeping.

Sleeping stage – Sleep proceeds in cycles of rapid eye movement (REM) and non-rapid eye movement (NREM), usually four or five of them per night. And NREM can be further divided into three sub-stages.

Sleep apnea – Sleep apnea is a type of sleep disorder characterized by pauses in breathing or instances of shallow or infrequent breathing during sleep.

Sleep report – A recording of data associated with sleep including the number of times users wake up during sleep, the time slept, the sleep quality index and a figure showing the stages of sleep over the sleep time.

REM – REM sleep is a normal stage of sleep characterized by the rapid and random movement of the eyes. REM sleep is considered the lightest stage of sleep so it would be better to wake someone up during this stage.

NREM – NREM(Non-rapid eye movement) sleep is, collectively, sleep stages 1–3, There are distinct EEG and other characteristics seen in each stage. Unlike REM sleep, there is usually little or no eye movement during this stage.

Health devices – some devices that can help your training or sleep by giving a report of your activities. Here we use Motoactv to record heart rate during sleep and use Zeo sleep monitor to extract sleep patterns from EEG data.

Database – The storage of all relevant Sleep Quality Assessment data, including users' profiles (name, age, gender, weight), heart rate data and the time that users sleep and wake.

User level – The mark distinguishes whether a user have access to the sleep quality of other users'.

2. SYETEM REQUIRMENTS

2.1 Requirements Summary

To fulfill the user requirements for the problem statement, Sleep Quality Assessment can collect the heart rate data from the mobile device that allow users to detect their sleep quality. The basic requirement for any user to be able to use Sleep Quality Assessment is that heart rate data must be recorded with a heart rate monitor during the user is sleeping. The report of the sleep quality with suggestions should be provided when the user finish the data collection. It is suggested the user to collect more sleeping data as possible as they can, so the application can provide a more accurate sleeping assessment. Also, the interface should be designed user-friendly, to confirm the user can use the application easily.

2.2 Function Requirements Table

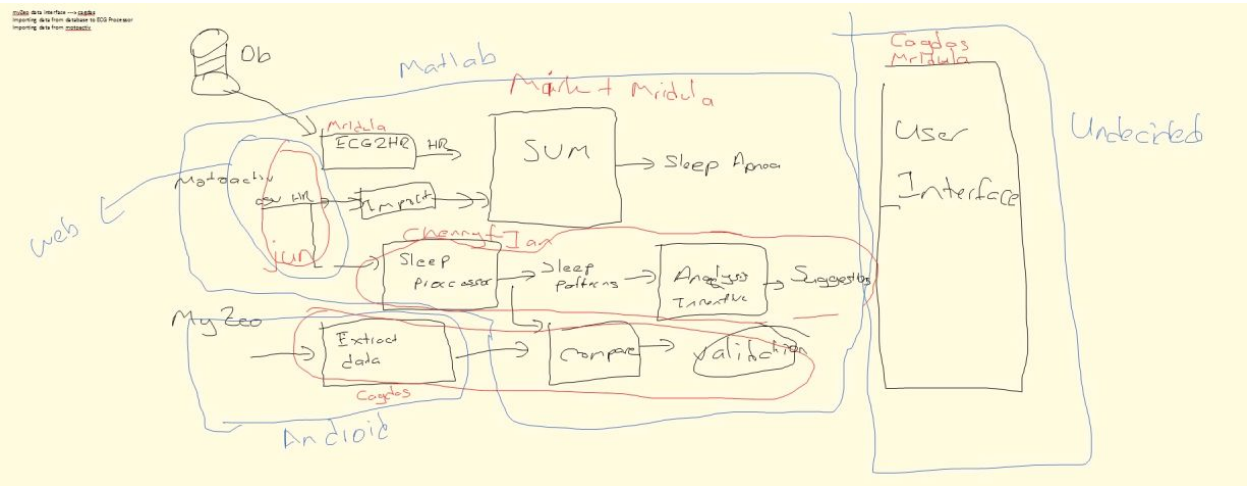
ID	Priority Weight	Requirement
REQ-1	5	The system shall be able to collect the heart rate data from user.
REQ-2	5	The system shall be able to store the heart rate data in the database.
REQ-3	5	The system shall assess the user's sleep quality.
REQ-4	4	The system shall be able to compare the data from ZEO and Motoactv.
REQ-5	4	The system should provide suggestions to user to improve the sleep quality.
REQ-6	2	The system should be able to diagnose sleep apnea
REQ-7	1	The system should be able to diagnose when the user gets up in between sleep and negate the impact of that
REQ-9	5	The system shall be able to record the sleep pattern of each specific user.
REQ-10	4	The system shall be able to give out the average amount of REM sleep and NON REM sleep of each user per day.
REQ-12	2	The administrator should be able to access the user account data.
REQ-13	2	The administrator should be able to retire a user account.
REQ-15	1	The system shall be able to arouse the user's attention to good sleep.
REQ-16	2	The system shall be able to divide user account into high-level and low-level. And high-level user could have access to check the sleep quality of low-level users.

2.3 Non-Function Requirements Table

ID	Priority Weight	Requirement
REQ-1	2	The system should be easy to use for all users.
REQ-2	2	The interface of the system should be friendly to user.
REQ-3	4	Each user must have a separate login
REQ-4	4	The privacy of the user is of utmost importance
REQ-5	5	User shall be not allowed to modify any data in the database.
REQ-6	5	User shall be not allowed to access the accounts of other users'.
REQ-7	4	The system should be maintained at a appropriate frequency.

2.4 On-Screen Appearance Requirements

We intend to create a secure user interface for every user to access his or her report. Given the fact that a central server can be used, the project is easily scalable. We need to gather more clarity on our user interface as we are concentrating on the actual data acquisition and classification of the project as of now.



ID	Priority	Requirement

	Weight	
REQ-1	4	Special Log-in Page
REQ-2	4	Upload raw date from Motoactv
REQ-3	3	Analyze uploaded data
REQ-4	5	Sleeping quality analysis reports-graphs of time & heart rate
REQ-5	4	Go back to homepage to re-upload data
REQ-6	5	Sleeping quality analysis reports -Suggestions to improve
REQ-7	3	Send apnea report to private doctor
REQ-8	4	Log off

3. FUNCTIONAL REQUIREMENTS SPECIFICATION

As a high quality sleeping is very important to everyone, people should consider about the quality of sleeping. Thus, this Sleeping Quality Assessment is suitable for any people. In other words, many end-users can be explored.

3.1 Stakeholders

This software is a health monitor that can be used by all the people. Everybody wants to have a good sleep at night. Thus, many people are the aim user for this Sleeping Quality Assessment. Here are some ideal stakeholders for our software.

- First, the people who have the disease of insomnia are the primary aim for this application. These people may be workers or students who suffer from the high working or studying pressure thus can't sleep well or simply adults and kids who experiencing the insomnia or some similar diseases which destroy the sleep hours. This category includes all age groups from children to adult who are suffering the insomnia and need to improve their sleeping quality.
- Second, the people who have not insomnia, but they want to record their sleeping quality and improve it.
- Third, the set of end-users is the people who would like to keep an eye on other people's sleep quality. They may be parents who want to supervise the sleep of their naughty kids or sons and daughters who pay attention to the sleep quality of their aged parents.
- The other possible users may include the athletes who need a good sleeping to keep their body in a good condition. Or the coaches and the experts who give advices to other people for gaining good sleep.

3.2 Actors and Goals

- **Low-level user**: a registered low-level user of the system;
- **High-level user**: a registered high-level user of the system;
- **Visitor**: an unregistered user;

- **Database**: records of all the sleep data;
- **Personal website**: the place where player can post their sleep quality;
- **Administrator**: a special user of the system who have top priority access to the system database.

3.3 Use Case Descriptions

3.3.1 Casual Description

Use Case	Name	Description	Requirements
UC-1	MonitorSleep	Allows all the users to get their sleep patterns from Database.	REQ-1,REQ-2
UC-2	GetSleepQuality	Allows all the users to get their sleep quality in a general way. Also detect sleep apnea if exist and ask the user whether send his/her record to a doctor	REQ-3, REQ-6
UC-3	GetSleepPattern	Allow all the users to know their sleep pattern.	REQ-9
UC-4	REMandNON-REM	Allow all the users to know the average amount of REM sleep and NON REM sleep hours per day.	REQ-10
UC-5	GetSuggestion	Allow all the users to receive specific suggestions concerning sleep quality.	REQ-5
UC-6	LowLevelRegister	Allow a user to register a low-level account with low permissions.	REQ-16
UC-7	HighLevelRegister	Allow a user to register a high-level account with high permissions. The high-level user can supervise the low-level user's record.	REQ-16
UC-8	Supervise	Allow the high-level user to gain access to the sleep quality of the several related low-level users.	REQ-16
UC-9	AccessUserAccount	Allow the Administrator to access a registered user's account.	REQ-12
UC-10	DeleteUserAccount	Allow the Administrator to retire a user account.	REQ-13

3.3.2 Fully-Dressed Description

UC-1

Initiating Actor: Low-level and high-level users
Actor's Goal: To get the original sleep data
Participating Actors: database
Precondition: The system always displays the menu of available functions
Postcondition: The original sleep data, i.e. heart rate and eeg would send back to users

Flow of Events for main Success Scenario:
→ 1. User selects the menu item "Check the data"
← 2. System displays a page asking user to choose a certain period of time
→ 3. User selects the dates
← 4. System prepares a select query a) signals the database b) retrieves the records and extracts sleep patterns, finally displays the recording on the screen

UC-2

Initiating Actor: Low-level and high-level users
Actor's Goal: To get the sleep quality report
Participating Actors: heart rate detector (Motoactv), database,system
Precondition: There is no connection problem
Postcondition: The sleep quality report would feed back to user

Flow of Events for main Success Scenario:
→ 1. User selects the menu item "Start monitoring" . System a) signals motoactv to collect data b)receives confirmation of start from motoactv.
← 2. Motoactv starts working and system informs user about the start of data collection
→ 3. User clicks "Stop". System c) signal Motoactv for a stop d) retrieves data with confirmation e) saves a copy of current data to database and system extracts sleep patterns and creates suggestions for current data. System also checks for a sleep apnea pattern from heart rate.
← 4. Sleep quality report would feed back to user
← 5. If sleep apnea detected system asks user whether he wants to send the report to doctor
→6 user choses 'yes' systems send results to doctor.

UC-5

Initiating Actor: Low-level and high-level users
Actor's Goal: To get suggestion for improving sleep
Participating Actors: system
Precondition: Raw data is already stored in the database

Postcondition: Provide a detailed suggestion about how to improve users' sleep

Flow of Events for main Success Scenario:
→ 1. User selects the menu item "Suggestion"
← 2. System displays a page asking user to choose a certain period of time
→ 3. User selects the dates. System prepares select query a) signals the database b) retrieves the results and extracts sleep patterns
← 4. System creates suggestions and displays the report on the screen

3.4 User Case Diagrams

The use case diagram is shown in figure 3-1. Low-level and high level User, Visitor and Administrator <<initiate>> all user cases, except for UC-3 (GetSleepPattern), UC-4 (REMandNON-REM), which are <<extend>> from UC-2 (GetSleepQuality) as sub-use-cases. Database store account information,monitoring data and relationship between low-level and high-level users, so it's <<participate>> in all use cases.

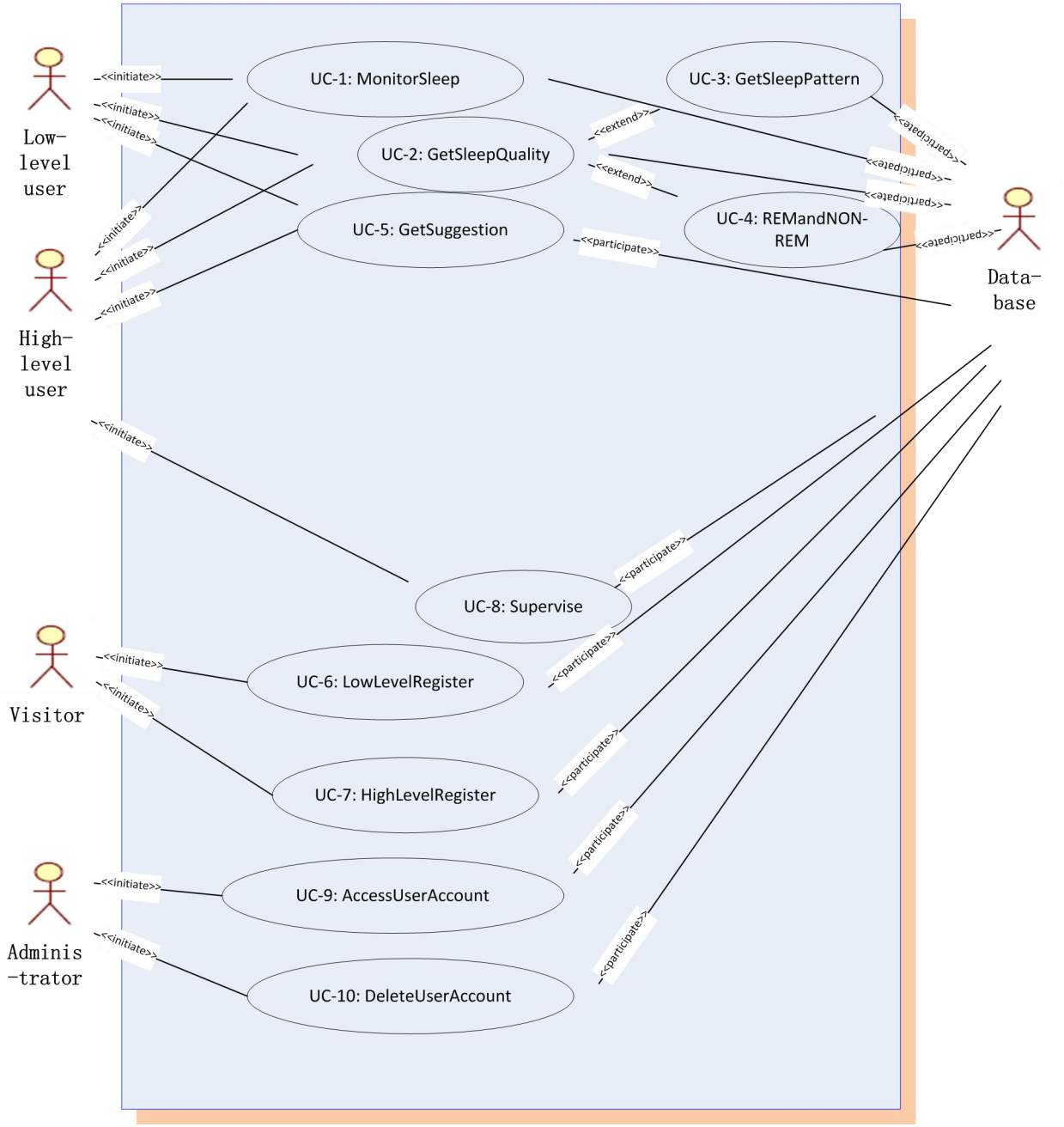


Figure 3-1 Use Case Diagram

3.5 Traceability Matrix

Use cases are designed to meet the system requirements, the traceability matrix in Table 3-1 shows the mapping relation between system requirements and use cases of this software.

	UC-1	UC-2	UC-3	UC-4	UC-5	UC-6	UC-7	UC-8	UC-9	UC-10
REQ-1	X									
REQ-2	X									
REQ-3		X								
REQ-4										
REQ-5					X					
REQ-6		X								
REQ-7										
REQ-9			X							
REQ-10				X						
REQ-12									X	
REQ-13										X
REQ-15										
REQ-16						X	X	X		

Table 3-1 Traceability Matrix

3.6 System Sequence Diagram

This section is the system sequence diagrams for the four important use cases described above.

The system Sequence Diagram of UC-1 is as Figure 3-2.

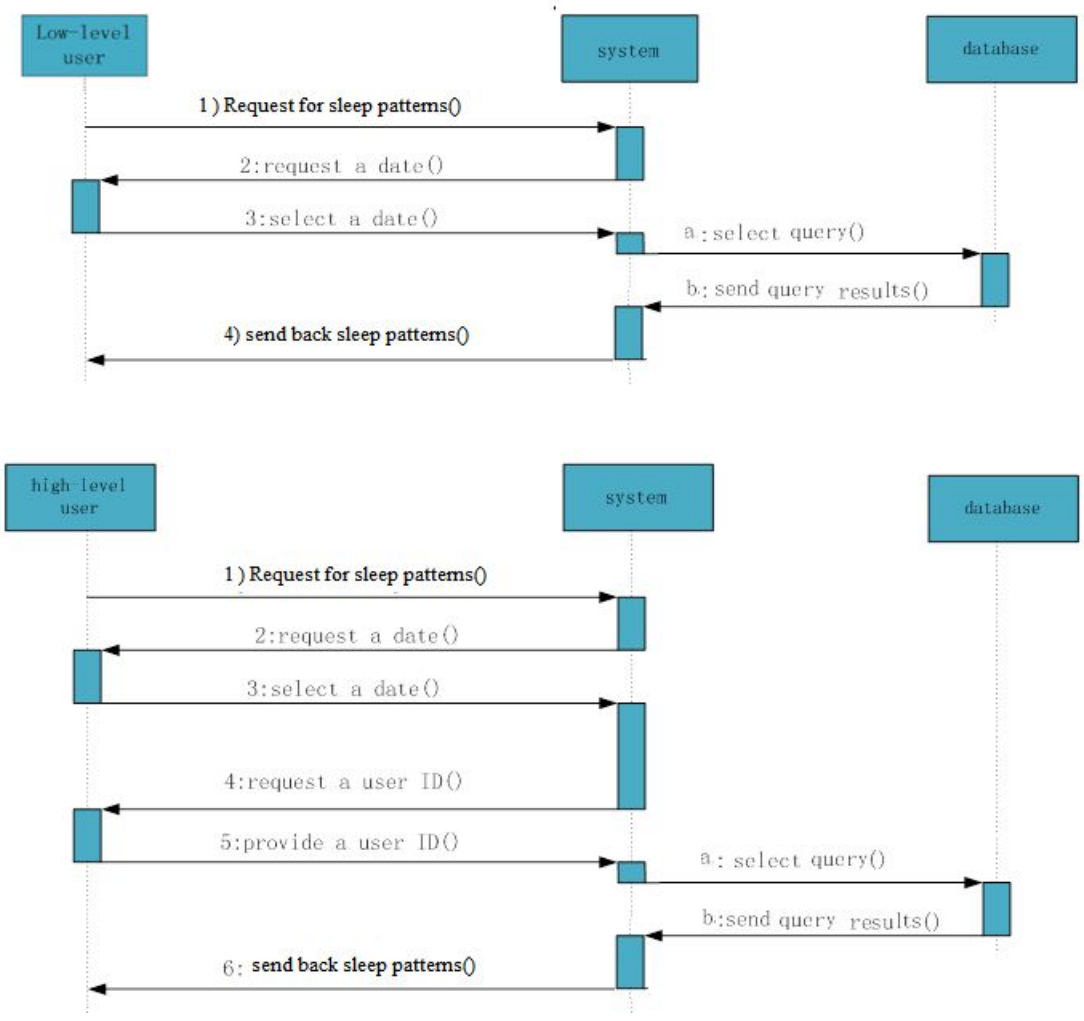


Figure 3-2 the sequence diagram of UC-1 MonitorSleep

The system Sequence Diagram of UC-2 is as Figure 3-3.

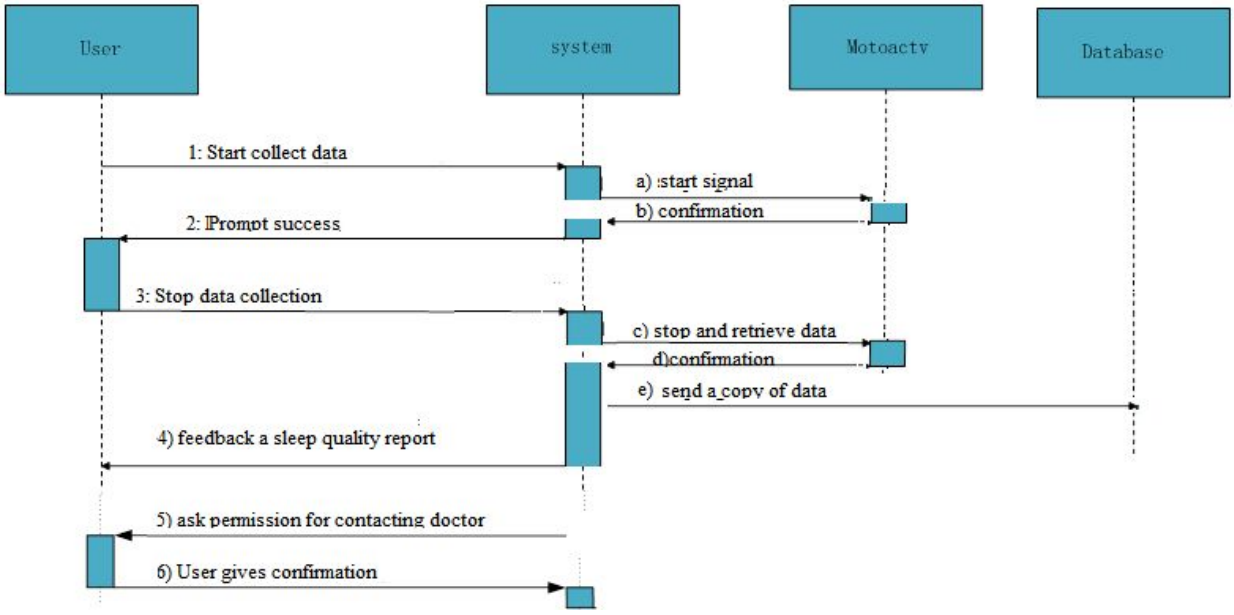


Figure 3-3 the sequence diagram of UC-2 GetSleepQuality

The system Sequence Diagram of UC-5 is as Figure 3-4.

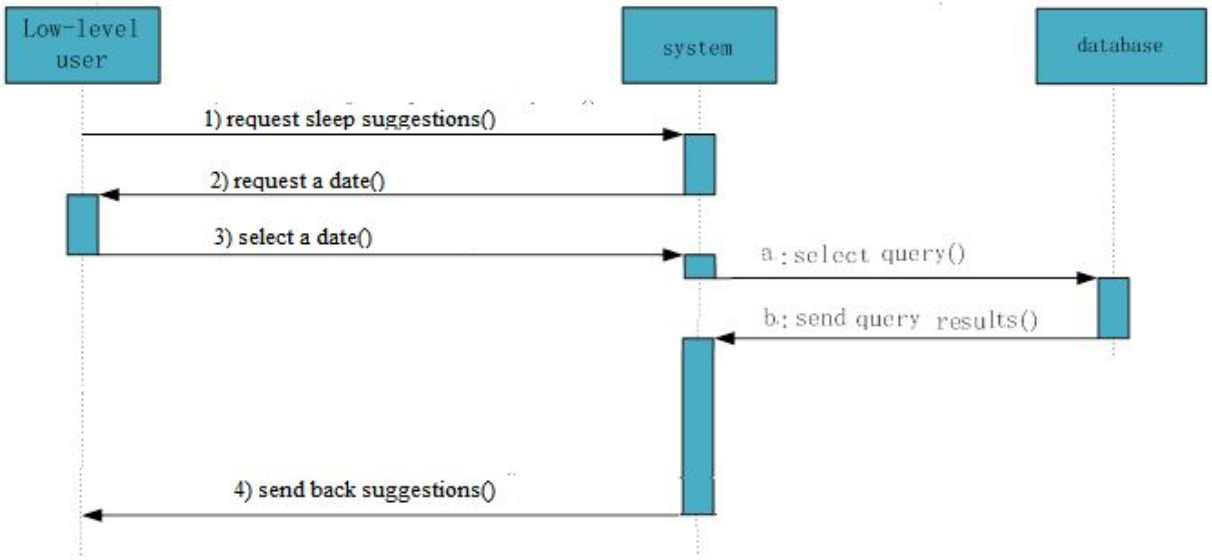
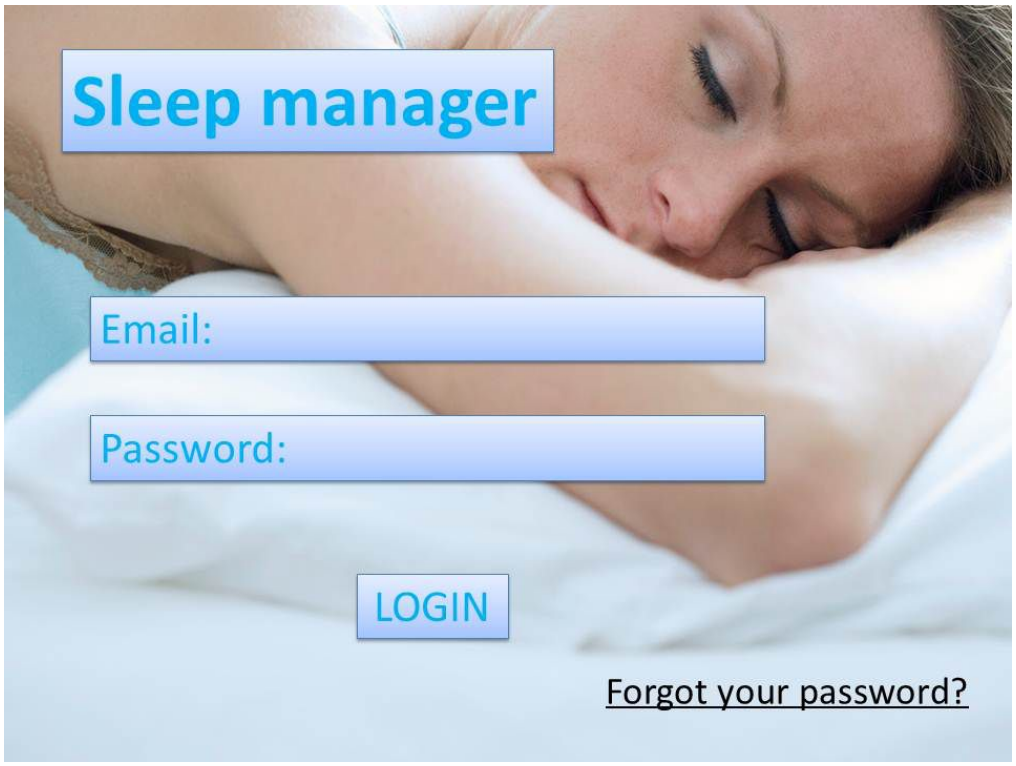


Figure 3-4 the sequence diagram of UC-5 GetSuggestion

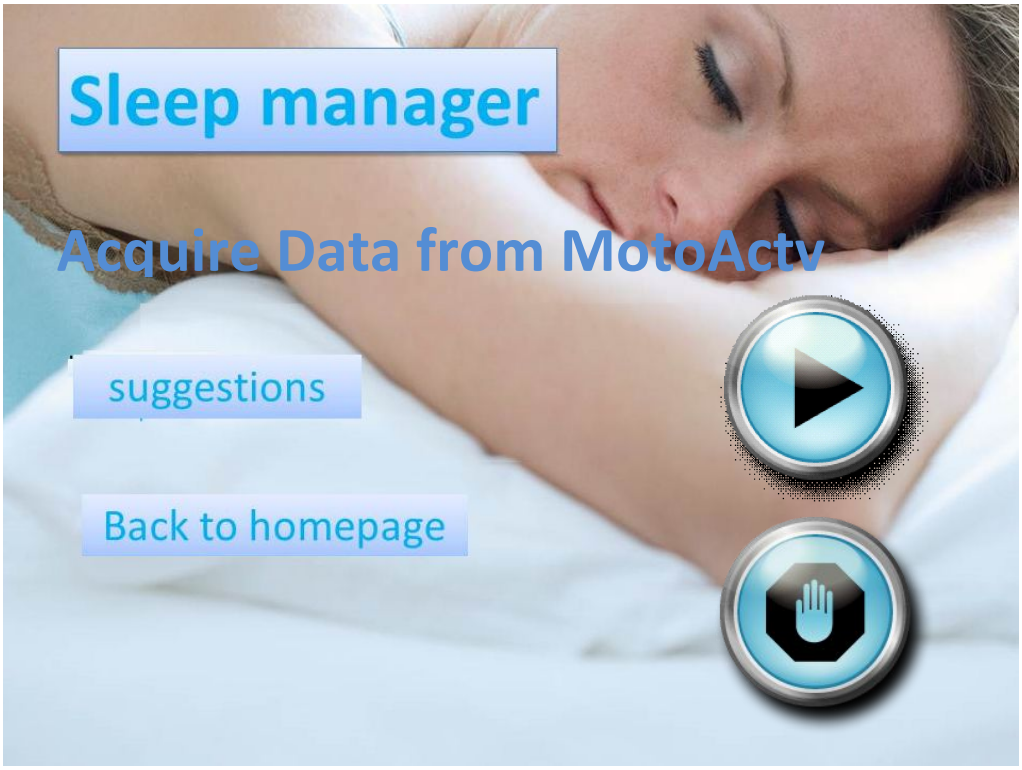
4. USER INTERFACE SPECIFICATIONS

4.1 User Interface Preliminary Design

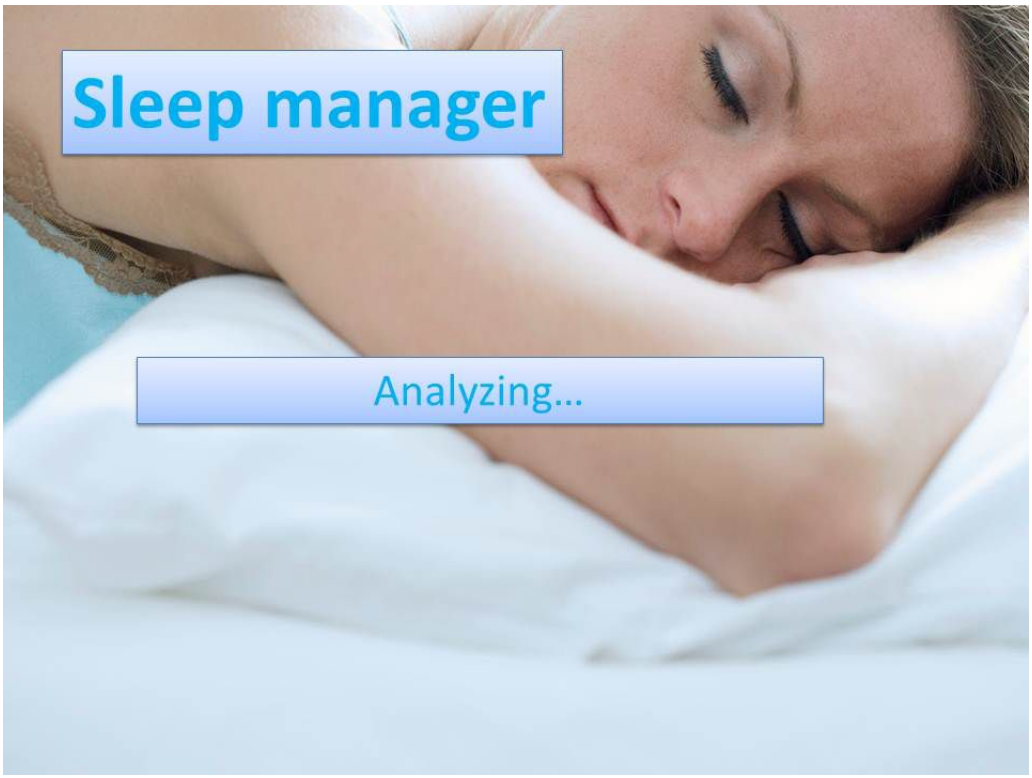
Here’re samples of our project user interface in progress:



Requirement-1 of On-Screen Appearance Requirements

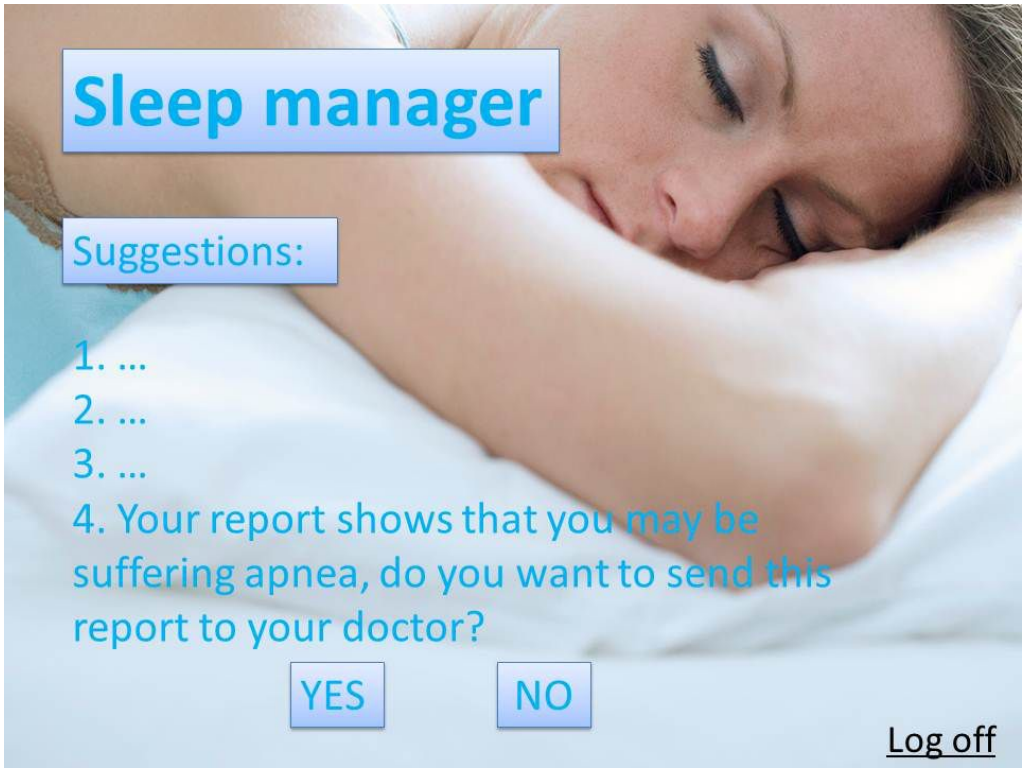


Requirement-2 of On-Screen Appearance Requirements



Requirement-3 of On-Screen Appearance Requirements

Requirement-4、5 of On-Screen Appearance Requirements



Requirement-6, 7, 8 of On-Screen Appearance Requirements.

4.2 User Effort Estimation

1. Login (one click, three key strokes)
    a. Enter Login details, user name, password (2 tabs and one enter)
    b. Press Enter
2. Press Start Button to start monitoring
3. Press Stop Button to stop monitoring
4. Press Obtain Report
5. Obtain History

5.0 DOMAIN MODEL

5.1 Concept Definitions

To analysis the domain model, we first derive domain model concepts and corresponding respo nsibilities from the formerly defined system use cases. Table 5-1 lists all the domain model concepts and corresponding responsibilities.

Responsibility	Type	Concept Name
Load Monitoring Data from Monitoring Device	D	Data Acquisition Manager
Store Monitoring Data onto the Data Base	D	Database Manager
Load Monitoring Data from Database to Sleep Pattern Manager	D	Sleep Pattern Manager
Use Sleep Pattern Manager to count heart rate, REM or non REM sleep and asses quality of sleep	D	Sleep Pattern Manager
Use Sleep Apnea Manager to Find if patient suffers from sleep apnea using SVM and MIT-ECG database	D	Sleep Apnea Manager
Login of User	U	Login Manager
Request Date for Data	U	Date Manager

Start Recording Data	U	Data Logging Manager
Stop Recording Data	U	Data Logging Manager
Report Handling	U	Report Manager
Generate Report of quality of sleep with suggestions using output of Sleep Apnea Manager and Sleep Pattern Manager and forward the report generated to the Report Manager	D	Sleep Diagnosis Manager
Manage User Permissions	U	User Account Manager

Table 5-1 The domain model concepts and corresponding responsibilities

5.2 Association Definitions

Some of the concepts defined above as domain concepts have to work in certain pattern to finis h some target, Table 5-2 gives the corresponding association definitions based on the defined d omain concepts.

Responsibility	Type	Concept Name	UseCase
Load Monitoring Data from Monitoring Device	D	Data Acquisition Manager	UC-2,3,5
Store Monitoring Data onto the Data Base	D	Database Manager	UC-1,4,5,8
Load Monitoring Data from Database to Sleep Pattern	D	Sleep Pattern Manager	UC-1,2,3,4,5,8

Manager			
Use Sleep Pattern Manager to count heart rate, REM or non REM sleep and asses quality of sleep	D	Sleep Pattern Manager	
Use Sleep Apnea Manager to Find if patient suffers from sleep apnea using SVM and MIT-ECG database	D	Sleep Apnea Manager	UC-2,5, 8
Login of User	U	Login Manager	All
Request Date for Data	U	Date Manager	UC-1,4,8
Start Recording Data	U	Data Logging Manager	UC-2,3
Stop Recording Data	U	Data Logging Manager	
Report Handling	U	Report Manager	UC-1,2,3,4,5,8
Generate Report of quality of sleep with suggestions using output of Sleep Apnea Manager and Sleep Pattern Manager and forward the report generated to the Report Manager	D	Sleep Diagnosis Manager	UC-2,4,5,8
Manage User Permissions	U	User Account Manager	UC-6,7,8,9,10

5-2 The corresponding association definitions

5.3 Attribute Definitions

Concepts	Attributes	Attribute Definition
Login Manager	User Interface	Store user input to the system, or show analyzed result to user.
Data Logging Manager		
Report Manager		
Date Manager		
Data Acquisition Manager	Data Read and Store	Read in and store data from the monitoring device.
Database Manager		
Sleep Pattern Manager	Data Analysis	Analyze Data
Sleep Apnea Manager		
Sleep Diagnosis Manager		
User Account Manager	Permission Management	Manage User Previleges

5.4 Traceability Matrix

	Manager	Database manager	Sleep pattern manager	Sleep apnea manager	Login manager	Date manager	Data logging manager	Report Manager	Sleep Diagnosis Manager	User Account Manager
UC-1		x	x		x	x		x		
UC-2	x		x	x	x		x	x	x	
UC-3	x		x		x		x	x		
UC-4		x	x		x	x		x	x	

UC-5	x	x	x	x	x			x	x	
UC-6					x					x
UC-7					x					x
UC-8		x	x	x	x	x		x	x	x
UC-9					x					x
UC-10					x					x

5.5 System Operation Contracts

- **MonitorSleep**

Precondition: The system always displays the menu of available functions

Postcondition: The original sleep data, i.e. heart rate and eeg would send back to users

- **GetSleepQuality**

Precondition: There is no connection problem

Postcondition: The sleep quality report would feed back to user

- **GetSuggestion**

Precondition: Raw data is already stored in the database

Postcondition: Provide a detailed suggestion about how to improve users' sleep

6. PLAN OF WORK

	41	42	43	44	45	46	47	48	49	50
Interface Design	■	■	■	■	■	■	■	■	■	■
Interfacing Hear Rate Monitoring			■	■	■					
Database Structure Design		■	■	■	■					
Algorithm Design				■	■	■	■			
Algorithm Test					■	■	■	■		
Debugging					■	■	■	■	■	■
System Test							■	■	■	
Report Draft	■	■	■	■	■	■	■	■	■	■
Report 1	■	■								
Demo 1			■	■						
Report 2				■	■	■				
Report 3									■	
Demo 2										■
Archive Documentation										■

Currently, we have established extraction of sleep quality assessment and sleep apnea models also we are done with development of Sleep Apnea Manager partially. However, there are still lot of challenges in terms of machine learning tools. Additionally, more work needs to be done

in interfacing heart rate devices. Also, database management part needs to be started and we haven't implemented user access control parts yet. This needs to be investigated and we will only get to it once the basic database is setup.

In terms of difficulties, although group members are quite collaborative and willing to contribute, we had partial issues when discussing domain models and during the requirement analysis. For that reason we have removed Requirements 8 to 11 due to low level of applicability.

7. REFERENCES

[1]Kendra Cherry, Stages of Sleep

[2] http://www.livestrong.com/article/105256-normal-heart-rate-sleeping/

[3]Effect of Sleep on Heart Rate Variability, Payel Ghosh

[4] Detection of REM sleep by heart rate, Masao Yaso, Atsuo Nuruki, Sei-ichi Tsujimura, and Kazutomo Yunokuchi, Proceedings of The First International Workshop on Kansei

[5] Heart Rate Variability During Waking and Sleep in Healthy Males and Females, Sigrid Elsenbruch PhD, Michael J. Harnish PhD, and William C. Orr PhD, Thomas N. Lynn Institute for Healthcare Research, Oklahoma City, Oklahoma

[6]The MIT BIH database website

[7]MOTOACTV