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Author	陳, 心愉(Chen, Xinyu) 加藤, 朗(Kato, Akira)
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Master's Thesis

Academic Year 2017

HealMove : Research of Reducing Prolonged Computer Use

Keio University

Graduate School of Media Design

Xinyu Chen

A Master's Thesis
submitted to Keio University Graduate School of Media Design
in partial fulfillment of the requirements for the degree of
MASTER of Media Design

Xinyu Chen

Thesis Committee:

Professor Akira Kato	(Supervisor)
Associate Professor Kai Kunze	(Co-supervisor)
Professor Matthew Waldman	(Member)

Abstract of Master's Thesis of Academic Year 2017

HealMove : Research of Reducing Prolonged Computer Use

Category: Science / Engineering

Summary

Devices like computers, smart-phones and tablets are getting widespread in this digital age, increasing young people are spending more time on them. It can do harm to health, especially when people spend consecutive hours on computers without proper breaks.This thesis has focused on reducing the prolonged computer use via creating a notification system. This system uses sensed data from pressure sensors setting on seats of chairs' for measuring users' situation and sending notifications based on data analysis so that users can be less distracted and the notification can be more accepted. Further, this system tries to encourage and guide people taking physical activity break via camera embedded in the computer and notifies people to change sitting posture from time to time via vibration.

Keywords:

Prolonged Computer Use, Pressure Sensor, IoT, Physical Activity Break, OpenCV

Keio University Graduate School of Media Design

Xinyu Chen

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Chapter 1
Introduction

Computers become part of our daily life and are now in widespread use. Researches showed that people nowadays spend more than 5.4 hours on computer for both work and entertainment [19]. It improves the quality of human life and brings great convenience, however, it can also do harm to people. People spending extremely long time on computer may cause excessive sedentary time (SED), which can increase the risk of many health problems like diabetes, cardiac attack and etc [28] [11]. Researches also showed that breaking up prolonged sitting can help reduce these health problems [18]. Another research improved that life satisfaction is positively associated with health behavior [12]. Even though standing up from time to time is not difficult and most people expect higher life satisfaction, it is still not easy for them to take actions voluntarily when they concentrate on screens of computers.

Further, for most modern people who are used to sit while they working or having entertainment activity, even though proper high-intensity exercises are already confirmed to be necessary and significant for health, it is hard for them to stand up and move their bodies from time to time during their sitting time, not to mention that 50 percent of Americans are reported not have any vigorous physical activity lasting more than 10 minutes per week [24].

There are some attempts for encouraging people sitting less during their work time. Sit-stand workstation is one of them. It helps reduce prolonged sitting time via using special desks [9], which costs a lot. This research is trying to find a simpler and easier way to encourage physical activity break and reduce a prolonged and consecutive computer use via using sensors collecting information about users and find a good timing [6] giving notification with an interaction way which uses web camera of computer to encourage users have a physical activity break. Also, this system uses vibration motor for notifying people change their sitting postures from time to time in order to avoiding keeping a same posture for a long period.

Timed-reminder is a traditional way to remind people taking a rest, but most break reminder applications use the method of setting a reminder alarm. However, this could be a distraction if users are not ready to take a rest when the notification is given. If they are concentrating on their works or if they are the middle of playing games, there is a very high possibility that they would ignore the reminder. Setting a reminder alarm is not enough to solve this problem because it just sends users information without getting any information from users so that their situation can be analyzed and the timing can be chosen.

One way to solve this problem is to find timing when users lose focus of what they are doing. The terminology of "breakpoint" [22] is used to describe the interruptive moments happened between two activity units. To find the proper "breakpoint", this research collects data of sitting pressure distribution and eye movements when people playing games for a prolonged and consecutive time and also recording their behaviors to observe how the data connected with their behavior pattern and how their behaviors get changed when they want to take a rest or lost the interest to that game.

Also, according to recent researches, physical activity break in prolonged sitting or from cognitive task can increase attention and reduce the risk of diabetes and obesity epidemic [7] [25]. Therefore, this research is also trying to find a way encouraging people doing physical activity when they decide to take a break.

In this research, many game players behavior has been observed and it turns out that to some of them, break time means watching video or news on their smart phones. Sedentary lifestyle develops with all those electrical devices like television, computer and smart phone, which has changed our life but also give birth to growing dependence to those devices. To help mitigate the harm caused by sedentary time, short physical activity can be effective [16].

Furthermore, if users are used to do some body movement, it could be a starting point for them to raise their health awareness and do more physical activities. A mirror is related to self-concern, self-consciousness and self-focused attention, in this thesis, when the notification is given to let them take a rest, computers web camera will be used to track users body movement and check if they follow the guide given by the notification system, so that people can see themselves on the computer screen.

As the group with the most contact with electronic devices and games [17], young adults are different from children or adolescents who are under the guardianship of their parents. They need to deal with academic or work pressure and psy-

chological factors behind their addiction to computer games are considered related with those pressures. Therefore, they could use computer games as a shelter.

According to my interviews with students who play games, they said that they spent extended time play games before exams or deadline and they even use their sleeping time playing games. Also, health awareness needs to be improved to promote healthy behaviors. The research focuses on finding out how peoples behavior pattern changes while playing games and how it is reflected on the data detected via pressure sensors.

Although there are lots of applications reminding people taking a rest, few of them trying to find the timing connected with their willing of taking a rest. This research is trying to find out a data model reflecting their behavior change when they are ready to take a rest. This research is trying to avoid giving notification when they are focusing on games or whatever they are doing because at that time, notification can be easily ignored.

1.1 Research Question

There are three main research questions in this thesis for mitigating the phenomenon of spending prolonged and consecutive hours on computer for gaming and working. The first one is how to measure users situation. This thesis tried eye tracking, posture detection and heart rate to measure users situation and mainly focused on using pressure sensors measuring users situation and finding a proper timing for notification.

Finding out the proper timing of notification is the second research question. This thesis observes people playing computer games and working to see how their situation change during their prolonged computer use and use both video and pressure sensors to record.

The third one is how to encourage a physical activity break and help people raise health their awareness. Instead of using traditional notification method like pop-up or sound message showing on the screen, this thesis tries to find out some methods more efficient and interesting and can encourage people taking physical activity breaks as much as possible and help people be more aware of their health.

1.2 Thesis Overview

This thesis described an economical and efficient way to help people avoid a prolonged and consecutive computer use and encourage them take physical activity breaks as much as possible via implementing a notification system based on sensed data of users' sitting situation. The main input here is the sensed data from pressure sensors detecting users sitting postures and the duration of how often they change their postures. According to data analysis and what kind environment users are in, the system will give notification via different methods. When users are in game mode, this system notifies them change their sitting posture if their sitting posture is not changed for 15 minutes via vibration. When their sitting and playing time is over 30 minutes, this system starts to find the breakpoint notifying people taking a physical activity break. In the work mode, for not disturbing users, the system tries to encourage a physical activity break when people leave their chair for having a coffee or going to restroom. According to video-based observation, when people concentrates on the screen, most of their sitting posture keeps the same and leaning forward. The system tries to find out the moment they change their sitting postures or the time users keep leaning backward. For this breakpoint, system uses web camera to guide people do some body movement. Because notifications are based on the sensed data, it can be less distracted and shows up on a reasonable timing. This thesis also explores the possibility of raising people's health awareness and breaking up their current habit of computer use via participants' feedback.

Chapter 2
Related Works

2.1 Traditional Notification Application

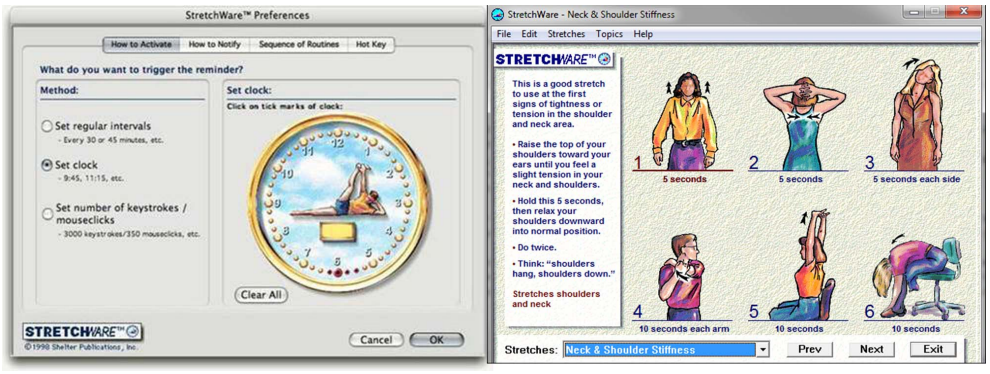
Traditional notification system usually relies on the fixed input data such as setting a timer for 40 minutes or counting 3000 keystrokes and etc. When the conditions are met, system will give the notification to remind users taking a break. The traditional notification system is very convenient and widely used. The efficiency and responsiveness of it is not very ideal, but it is very easy to be developed and used on all platforms. It shows the demand of notification system.

2.1.1 Web Service:Protect Your Eyesight

The web service helps people protect their eyesight when they browse websites. It is depended on a 20-20-20 rule which is promoted by The Canadian Association of Optometrists. It says when people staring at screen for every 20 minutes, they should take a 20-second break and focus their eyes on something at least 20 feet away. This web service followed this rule and set a timer to help count the using time. When the time is up, it will give notification and if users choose to take a rest, it will black out the screen. `http://www.protectyourvision.org/`

2.1.2 StretchWare

StretchWare as illustrated in Figure 2.1 is software which needs to be installed in the computer. It can get the data of keystrokes and mouse clicks. When the numbers of keystrokes and mouse clicks reach some level, it will give notification suggesting a break. Also, the way this software used to encourage people take a physical activity break is showing people pictures of stretch guide, which can be easily completed in an office.



(Source: Stretchware Official Website [5])

Figure 2.1: StretchWare using key strokes, mouse clicks and clock set as the assessment of giving notification and encourage users doing stretch

2.2 Notification Based on Sensor Data Analysis

Notification based on sensor data analysis is widely used such as preventing drowsy driving, which is different from traditional way of setting reminder alarm. It is based on the real-time data, data analysis and it has higher efficiency for being more specific and targeted. There are also many other applications giving notification due to users data in order to improve some specific problems.

2.2.1 Smart Glasses: J!NS MEME

J!NS MEME as illustrated in Figure2.2 are smart glasses with 3-point electrooculography (EOG) sensors located on the nose pads and six-axis sensors in the eyewear. EOG sensors are used to detect blinks and eye movements via detecting the changes in electric potential. The theory behind it is that human eyeballs have positive electric potential on cornea side and when people blink or move eyeballs, the positive electric potential will change so that these EOG sensors can detect. The six-axis sensors are used to detect motion and rotation speed and body movement can be reflected in the data which measured by six-axis sensors. These two kinds of sensors ensure that J!NS MEME can be used to detect users physical condition including concentration level, fatigue and composure [14] [13].

A recently research uses J!NS MEME to promote healthy habits for knowledge workers [15] via detecting users situation such as head angle and blink duration. This research is trying to improve the computer vision syndrome(CVS) and

(Source: J!NS MEME Official Website [4])

Figure 2.2: Smart Glass J!NS MEME

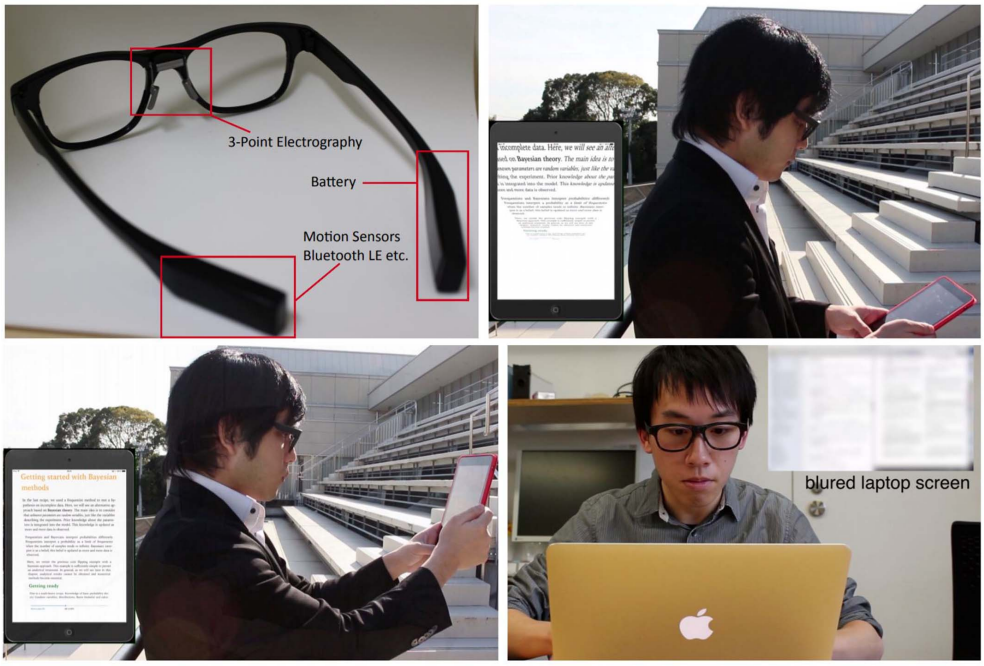
headache caused by a prolonged improper posture. When the data received and analyzed by J!NS MEME says that their blink duration is longer than the regular intervals, the system will make the screen blurring until users blink. Also when the flexion angle of users head is over 60 degree and longer than 40 seconds, the device will tilt the contents on the screen to make it hard to be read until users correct their head posture as illustrated in Figure2.3.

2.2.2 Nekoze

Nekoze [27] is an application which monitors users postures and if users postures are considered as an improper posture, it will give notification and until users correct their posture, the notification will not disappear.

During the study, it gives notification with three stimuli: notification on the top bar, notification and sound, a screen flash, just sound. This study is trying to improve the neck pain and other spine related injures due to improper posture. It developed application on both computer and mobile devices. On computers, it detects users head postures via computers camera using the face detection libraries in OpenCV.

Furthermore, on mobile devices, it uses smart glasses, J!NS MEME, to detect head angle via the accelerometer sensor embedded in the smart glasses. Notification will be given when the head angle is over 19 degrees as popping up a message or doing a screen flash via changing brightness and contrast. According to users feedback, the way of notification should draw more attention such as using vibra-



(Source: MEME:smart glasses to promote healthy habits for knowledge workers [15])

Figure 2.3: Using JINS MEME to promote healthy habits for knowledge workers

tion on smart glasses so that people will not ignore it and be willing to correct their posture and what will make it better is using some method to induce the change subconsciously such as muscle stimulation.

2.3 Adaptive Notification

Considering the great amount of information we need to receive every day from various application from smartphones, computers and devices in this ubiquitous computing age, a notification showed in an inopportune time could be a great distraction and also can be easily ignored. This study confirmed that finding an opportune time to sending people notification can lower their cognitive load and interruption overload and gain more responsiveness.

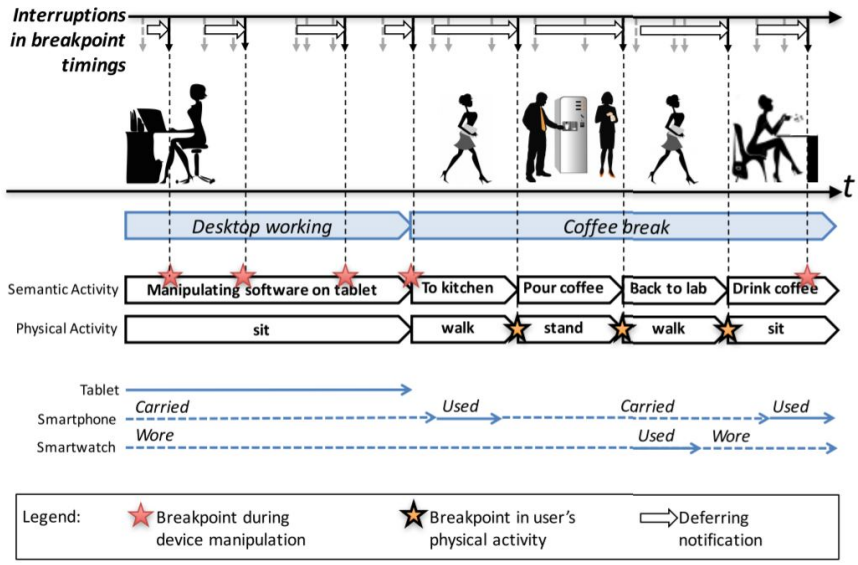
And this study developed a real-time interruptibility estimation logic based on breakpoint as illustrated in Figure2.4 detection inside the Yahoo! JAPAN Android application [22] . Breakpoint means the borderline between two contiguous units of user activities and is considered as a time point when can add less impact on peoples cognitive load and notification can get more responsiveness. The breakpoint is divided into two classes as physical activity breakpoint and device interaction breakpoint.

This study focuses on physical activity breakpoint for its efficiency and accuracy. Physical activity breakpoint can be detected by devices like smartphones or wearable watches, for example, those devices can get the data of users body movement and analyze their behaviors like walking or sitting.

Therefore, their changes in activities can be detected and those detected changes will be selected as opportune timings for notification. According to the user study, it found that an opportune-timing notification delivery connected with detected breakpoint can increase the content click numbers and users engagement level.

2.4 Pressure Sensor

Pressure sensors can be used to classify sitting postures [20] and recognize object [30] and even can detect high-level activities [10] while people sitting such as typing or eating via weight distribution analysis. In [10], they extracted information of sitting postures or activities using pressure sensors mounted under the a chairs four legs. Analyze the voltage change related to resistance change when the pressure



(Source: Attention and engagement-awareness in the wild: A large-scale study with adaptive notifications [22])

Figure 2.4: Two Types of Breakpoints - Device Interaction and Physical Activity

gets changed. Also, pressure sensor also can be used for object recognition such as distinguishing children, women or men sitting in an automobile. Pressure sensors are proved to be a good tool helping collect users sitting situation and as an input for an interactive system.

Chapter 3
System

3.1 System Design

The prototype of this system is divided into two parts: hardware and software. Hardware part uses four pressure sensors connected to Arduino to detect users situation via their sitting data. These data are sent and analyzed in the system and according to the data analysis, the system determines how to give notifications.

Further, the methods of giving a notification uses web camera embedded on computer to check users movement via using motion detection method in OpenCV. When users follow the guide given by this system, they can go back to their games or works. It also use vibration motor for encouraging users changing their sitting postures and avoiding keeping the same sitting posture for a long period. There are two modes in this system for work or game. For different modes, the notification timing and methods changes. This system design is followed by video observation of users who uses computer playing games and working. According to the observation, experiments are set to detect the data to see if the results can be reflected on the data.

3.1.1 Approaches

For finding out the timing of giving a notification, several methods are tried in the process of this research to measure users' situation. One is eye blinking analysis via web camera and this method is based on fatigue detection theory. When people feel tired, their blink rate reduces and the duration increases. For people who play games, the eye movement and blink rate changes when they are focus or not. According to the observation of people who playing game, their eye movement is more than people who use computer doing other things because most game needs people seeing the whole screen and check what to do next. This method using web camera and OpenCV to detect users' faces and then detect their eye area via

Haar Cascade feature-based classifier. Then set the region of interest(ROI) and use color detection of pupil to check eye blink rate.

However, using web camera to check users' situation has several problems, the first one is about their personal information, in this digital age, keeping web camera on can be uncomfortable to most people which makes them feel like they are watched. The second problem here is this method takes up much computation load and slows down computer. The third problem there is individual difference while playing games and the instability. Lighting situation can be a factor to cause the failure of eye blink detecting. Playing games or working is different from driving, the breakpoint does not must to be when the users' body feel tired. The physical situation can be separated to their mental situations.

Furthermore, the smart glasses called J!NS MEME is also tried in this research for detecting both users' eye movement and body movement during their prolonged game and work time. Their data are also compared to their daily life without sitting in front of a screen. It turns out when they looking at the screen, their average blink rates are lower than usual and the average duration is longer. However, at the end of one session of the game or when people lose certain focus from their work, the eye blink rates raises and the duration is short. There are still several problems using smart glasses. The first one is that wearable devices like this is not suitable for people who already had glasses and also, according to participants' feedback, it is not very comfortable for wearing it for the whole day.

Then a eye tracking device called Tobii is tested in this research. It is set near the computer screen and to catch users eye gazes. By using and editing the software development kit of Tobii [29], it can get the x and y coordinate of the gaze point. According to the gaze point, where users are focus on can be analyzed. However, this method turns out to be not suitable for detecting the whole screen without referring some certain place for users to look. The individual difference and computer using habits make the standard hard to be set.

After all these experiments and trials, the approach of using information of sitting as inputs is tested. Using simple and cheap pressure sensors and Arduino to detect users' situation is reasonable in this research for finding out when to give notification. When people play games or work on their computers, their most common status is sitting. According to the changes and duration on their sitting situation, notification can be arranged to encourage people having a physical activity break.

3.1.2 Physical Background

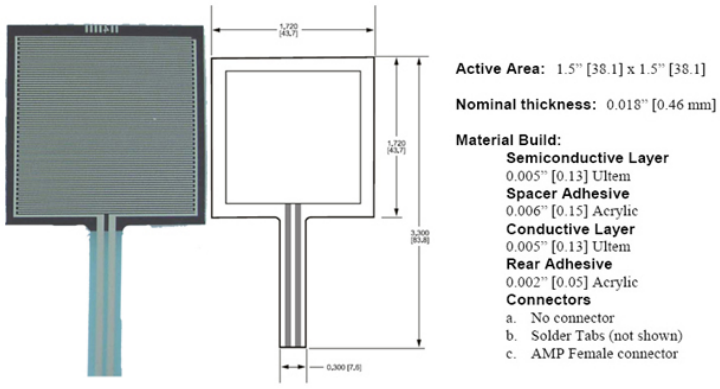
Sitting is the most common state for people working or playing games on their computers. A prolonged sitting and computer use can be harm to people's health. Because sitting in the same posture for a extended periods of time can lead to discomfort, this system also tries to encourage people changing their sitting postures from time to time.

The video-based observation of people who playing games and work on their computers shows several behavior patterns. When people who play games, leaning forward is the most common state because they uses mouses and keyboard to control the games and also need to watch the screen with attention. Usually, when one session of the game is over, they swings from front to back for a while or move their bodies sightly for relaxing their muscles. Because game requires a lot of attentions, at the end of one session and before new session starting, their relaxes themselves for keeping better attention in next session. This is for the games which need attention and for some game not have obvious boundary between two sessions like some story-telling game, users may stay a relaxing state playing it. They often keeps the same posture for extended periods of time at this situation, which is often the posture of leaning backward.

For people who use computers for working like writing papers or coding, their sitting postures can be more free. Some times they lean forward and sometimes they lean backward. Each sitting posture stays a quite long time when people concentrate. Even though they moving their bodies slightly or changing their sitting center from front to back from time to time, it dose not mean that they are losing focusing. If it is just a short-time body movement, it can also be some unconscious move for help themselves regathering their attentions. But they often move their chairs or sitting postures for a relative long time when they are losing focus. During the working mode, people stand up for going to restroom or having a cup of coffee for themselves. This can also be easily detected by pressure sensors.

Four pressure sensors are set on the four sides of a normal chair seat with certain distance to detect users sitting pressure distribution while they playing games. The four sensors are connected to an Arduino and sending data to computer for analysis. The sensors are Force-sensing resistor FSR402 as illustrated in Figure3.1, which is low-cost and easy to get and use.

The system can provide information about how weight or force distributed on the seat when people use their devices and how the distribution change during their two activity units. Considering that when they are sitting down, their body



(Source: Force Sensing Resistor Data Sheet [2])

Figure 3.1: Force and Pressure Sensor: Force Sensing Resistor402

trunk keep relatively stable when they concentrate on what they are doing.

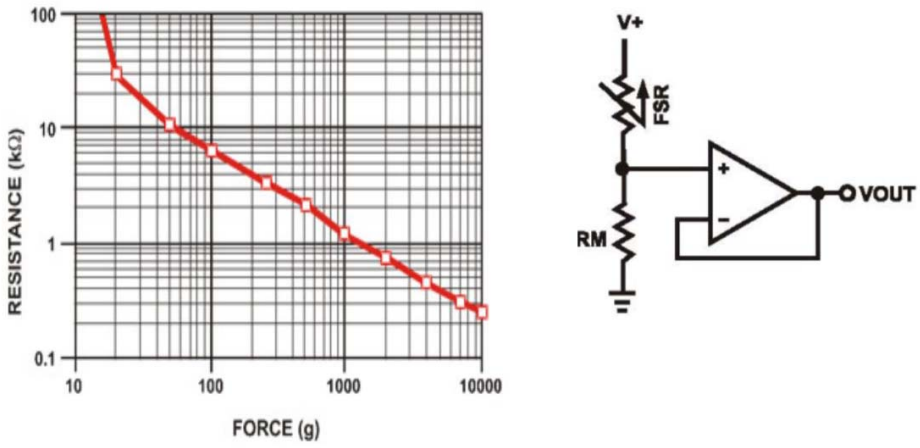
Those four sensors divide the seat area into nine equal divisions and their weight center can be known from sensor data analysis. Several sitting postures can be found out like leaning forward, backward, right and left, one leg over another.

3.1.3 Pressure Sensor

Considering in this computer age, there are increasing people using devices like computers, smartphones and tablets every day for a prolonged and consecutive time without proper rest for working and entertainments. At most time, people are sitting and using those devices. Therefore, information of sitting could be a good choice for finding the breakpoint.

In this research, force-sensing resistor FSR402, which is low-cost and easy to get and use are used to detect both users postures and changes between their two activity units. The circuit is composed by several 10k resistors series connected each pressure sensor and the resistance of FSR sensors is from 100k to 0.3 k and when the force received from 0.01kg to 10kg as illustrated in Figure3.2.

The pressure sensors are connected to the analog input pins of Arduino from A0 to A3 in order to get the data of output voltage. The resistance of FSR sensors is from 100k to 0.3 k and when the force received from 0.01kg to 10kg and when the resistance of serial connected resistor is different as illustrated in Figure3.3, the voltage output is different. When the sensors detect force, there will be data



(Source: Force Sensing Resistor Data Sheet [2])

Figure 3.2: Force Curve and Schematic of the Force Sensing Resistor

of output voltages sending to computer via Arduino. The output is described by the equation:

$$V_{OUT} = \frac{R_M}{(R_M + R_{FSR})} V+$$

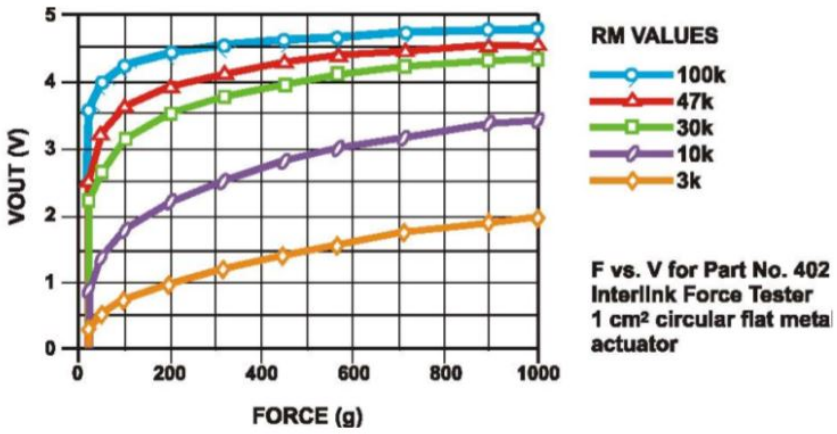
When the force getting bigger, the resistance of FSR is getting smaller, so that the output voltage will increase. In the program for Arduino, the range of output data is set from 0 to 1000 connected with the output voltage.

3.1.4 System Design

The four pressure sensors are marked as F_{fr}, F_{fl}, F_{br}, F_{bl} and they received data from each side of the seat to show how the pressure distributed. Four matrix is used to save the data from four sensors in order to analyze them. The program will check the data it received now and compare it with the last one to see how much it changed to find out if the distribution changed or not.

The circuit design as illustrated in Figure3.4 here uses four force sensing resistors and one Arduino Uno Rev3 board to build this hardware part.

According to observations in this research, when people sit for working or playing games, their body trunk will not move often when they are focus on what they are doing. When people concentrate on screens for playing games or working, their main sitting posture is leaning forward and the more they concentrating on



(Source: Force Sensing Resistor Data Sheet [2])

Figure 3.3: The Relationship Between RM Values and VOUT

the screen, the more they are leaning forward. During the focusing time, their sitting posture is different from relax time or their normal sitting posture and the center of weight will moving forward.

3.2 System Scenario

This system can be used in both work mode and entertainment mode and even though this research concentrates on analyzing users' behavior during their game time, it still discusses the possibility of using it during work time. Considering that nowadays people spend most time sitting using computers for working, watching video or playing games, a more smart notification system can be used to encourage people have healthier tech life. This system tries to use simple and cheap pressure sensor and web camera of computers to help more people realize the importance of taking physical activity breaks as much as possible.

Pressure sensors can be easily set on chair seats and the method used in this research to analyze data for detecting users' situation does not take too much random access memory of users' computer. Different ways of notification can be chosen in this system in order to meet users' different needs. People now pay more and more attention to their health but their already formed sitting habit

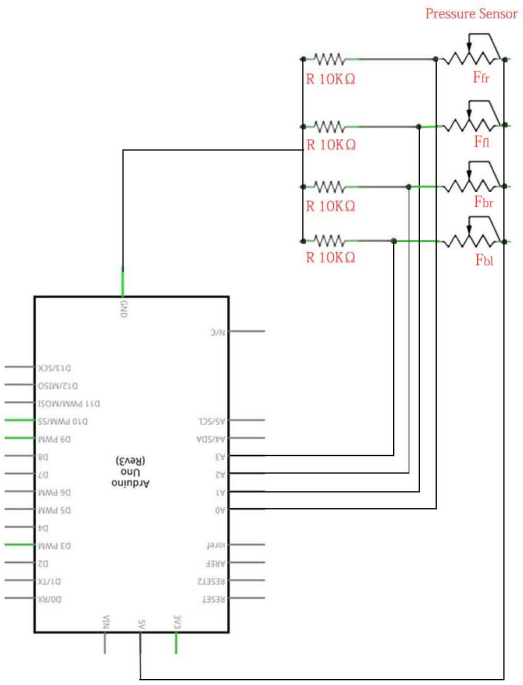


Figure 3.4: Four Sensors on Seat with Certain Location

stops them from acting more healthily. Evidences shows that proper intentional interruptions for breaking up prolonged sitting can improve work engagement and attentiveness. The scenario is related to these problems that people faces and shows how this system can help people get more healthier.

3.2.1 Game Environment

Game creates a virtual world for people hiding from the reality world where they take pressure for work, academy or family. Ten college students who play games all said that they play games for extended time before the day of their tests or submission deadline, and although they do want to take breaks, it is not easy to do on their own.

There are various computer game genres, such as Action Game, Real-Time Strategy Game (RST), First Person Shooter (FPS), Role-playing game (RPG) and all these games have sessions or save point. In game environment, this system give notifications via two kinds of stimulus. One is vibration and another one is using web camera. Sitting straight is known as the most healthy sitting posture, however, when people play games, sitting straight is not the most convenient posture for them. Instead of asking people to sit straight, changing sitting posture from time to time seems to be a better way to help them relax their body. According to ergonomic theory, keeping any posture for a long time is not good for health because it can cause musculoskeletal discomfort.

This system uses four pressure sensors to detect users' sitting postures and changes. When users does not change their postures for over ten minutes, the vibration motor set on the seat will start to work in order to remind people change a sitting posture. Considering that users are focusing on the game, the vibration notification can be annoying but have little influence to their game playing. The vibration will only stop when user change their sitting posture.

When the data shows that users are sitting for over forty minutes, system will try to find the breakpoint to notify users take a short physical activity break. According to the observation, when people focus on their screen and play games which need users use keyboard or mouses frequently, their main sitting posture would be leaning forward. The center of weight also moves forward than their normal sitting posture.

When one session of game is over, their sitting posture would have slight change or big change. The usual pattern according to observation is leaning backward or swinging. The system will capture the change and black out the screen using

web camera to catch a real-time video stream. Some points shows on the screen to guide users to move their body to reach the area where the point is in.

This interaction between users and this system does not just try to add some fun but also consider that when people see their face and body, their self-awareness can be raised. Self-awareness is connected to their health awareness [23]. Even though for people, standing up is not a hard action to take, it is hard to break the sitting habit.

Previous researches improved that standing up as much as possible during a prolonged sitting time is good for both health and raising attentiveness, but remembering when to stand up and how often should they stand up or move their body is a heavy cognitive load to people. Some researches also investigates how a sit-stand workstation can help people reduce their sitting time [8]. However, a sit-stand work environment costs a lot and is hard to promote for now. The traditional way of setting remainder alarm can add cognitive load if the timing is not proper. When people concentrate on the screen, notification on the screen can be very disturbing and unpleasant. This system tries to solve this problem using sensors and tries some different ways to notify people to see what kind of stimuli works best on certain situation.

3.2.2 Work Environment

In work environment, concentration means much more important to people. However, proper physical activity breaks during prolonged sitting time help raise work engagement [21] [26]. For not disturbing people while they working, according to the sensors data analysis, when the weight center is not changed much and their postures are detected as leaning forward, considering users are concentrating. Users' sitting time is also taken into consideration. For example, when students works on their graduation papers and spend all day on their computer, proper physical activity breaks is very important but when to take a break is hard for themselves to track. At this time, according to the video-based observation, most of them spend their break time playing smart phones or talking to their friends instead of standing up and moving their body. Brain rest is another important kind of rest, however, brain rest is not enough. Before they taking their brain rest, their sitting situation is quite unstable. This can also be easily detected by the pressure sensors. For work environment, finding a breakpoint to do the notification is more important for workers to accept without distracting them from their work. The time people stand up for going to rest room or having a cup

of coffee is a good timing for giving notification of physical activity breaks. For people sitting a extremely long time, their unstable sitting situation can be used as a timing for giving notification.

Even though they speed all day on the screen, it does not mean that they do not have other behavior rather than just typing. Going to the rest room or stopping for some coffee can become some signals for sending their notifications. The physical activity break in the work environment is more like a game for them to play and in the future, it can be a social network game for them and their friends to play when they work on their papers and want to spend a short time together taking a rest. For work environment, the system is designed to give notification of taking a physical activity break when the sensors detect that no one sitting on the chair.

Chapter 4
Implementation

This chapter describes how this system extract information from users' sitting data via pressure sensors, the method used to analyze data and how web camera is used to do motion detect. Hardware and software design will also be introduced in this chapter.

4.1 System Overview

Firstly, this system uses four pressure sensors setting on chair seats to get users' pressure distribution data while they are sitting. The four sensors are set with certain distance and on certain location as in Figure4.3. The four sensors are marked as F_{fr}, F_{fl}, F_{br}, F_{bl}. F_{fl} is responsible for data from front left, F_{fr} is for front right, F_{bl} is for back left and F_{br} is for back right. The four sensors are in serial connection with resistors and are connected to Arduino for sending data. When sensors receive forces, the sensor resistance changes so that output voltage changes. The system obtains the raw data of different sensors and put them into different matrices. Then system analyze these data and find out the sitting center and their sitting postures in order to understand users' situation.

According the video based observation, the system analyzes the data and detect users' situation and the duration of they keeping one posture. Further, in this thesis, a more interaction method is used to notify people taking a physical activity break rather than a traditional way sending notification. This system uses web camera and the motion detection method in OpenCV to detect users' body movement and encourage them take a physical activity break via giving random guidance on the screen to ask people move at that direction.

According to data received and analyzed in experiments, six different sitting postures can be classified due to their features. Also, pressure applied to the seat area aggregated into nine divisions. According to the data analysis, weight center

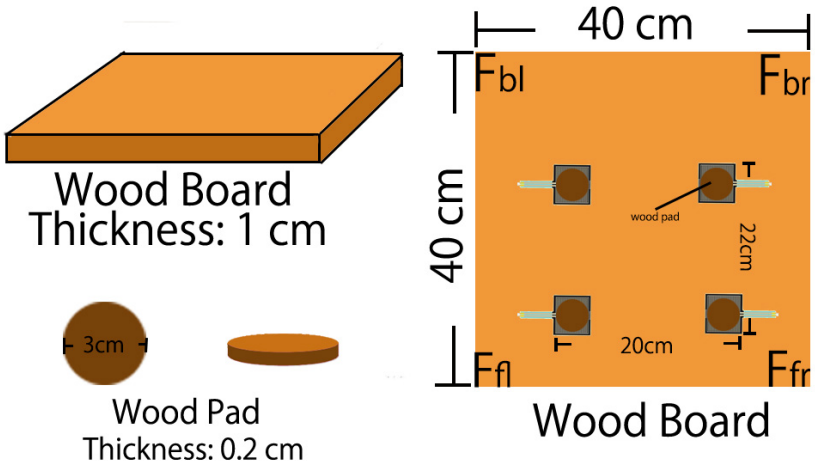


Figure 4.1: How sensors set on the seat

Figure 4.2: Front View

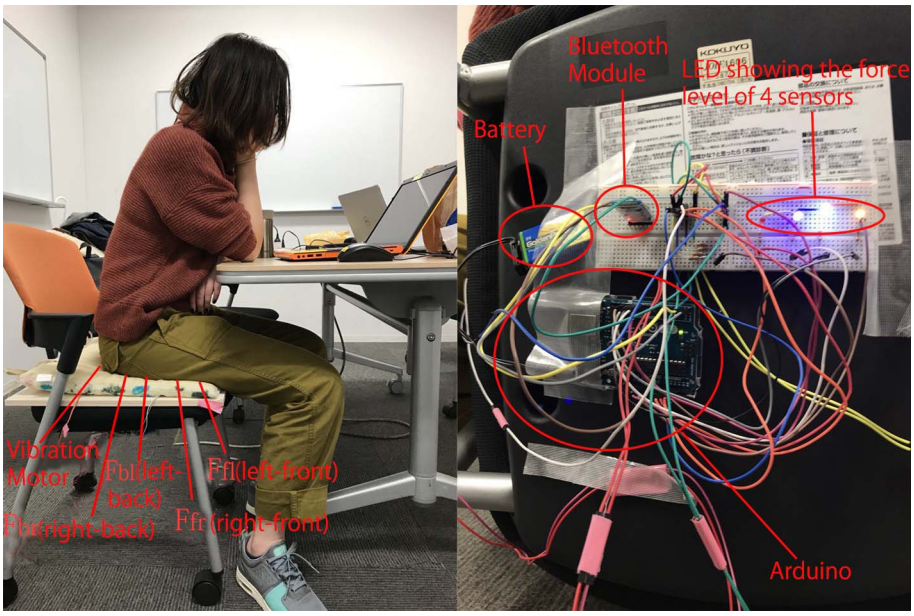


Figure 4.3: User Sitting on Pressure Sensors

can be found in which division. Also, the duration can be detected. The current sensor data are saved into different matrices due to sensor number.

4.2 Hardware

Pressure sensors are used as main input in this system and it connected with Arduino. Except the sensor part, it also has Bluetooth module for sending data without using wire and vibration motor part for giving users stimuli via feeling. The hardware part also includes several resistors and LED for checking if all sensors work well.

4.2.1 Film Pressure Sensor

Film pressure sensor is simple, cheap and also very thin, which is suitable for setting on chair seat. The pressure sensor can transfer force data into numbers and send it to system via the change of its resistance. The basic theory here is when the force is bigger, the resistance of the pressure sensor is smaller so that the voltage output changes. For the Arduino program part, the number of voltage output is reflected from 0 to 1023. A bigger number means more force and

pressure. Each sensor is also connected to a LED with different lighting colors and the brightness of LED gets brighter when the force gets bigger. The LED can help check if all the sensors work or not before recording data. The four film pressure sensors are set on four different directions on chair seat to collect data as illustrated in Figure4.4.

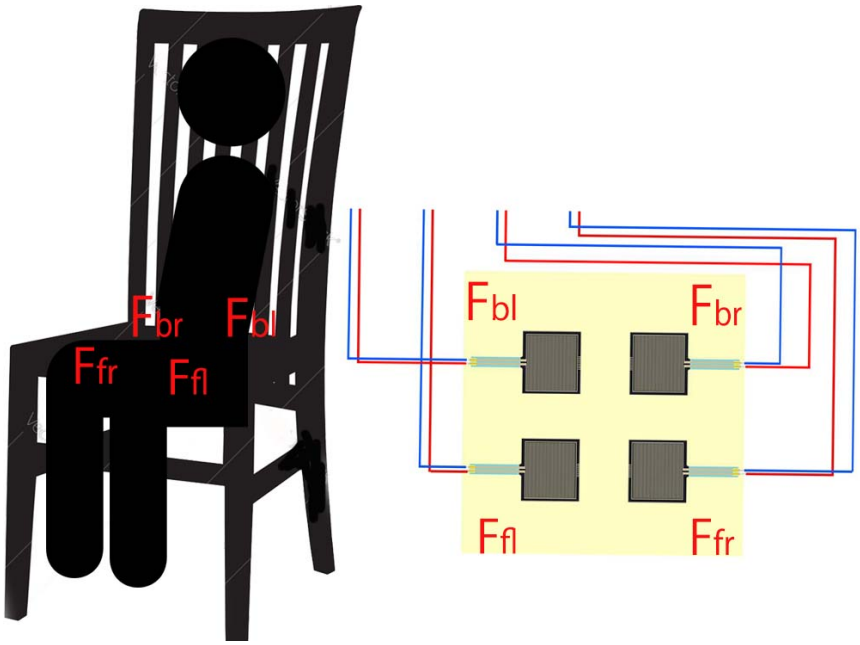
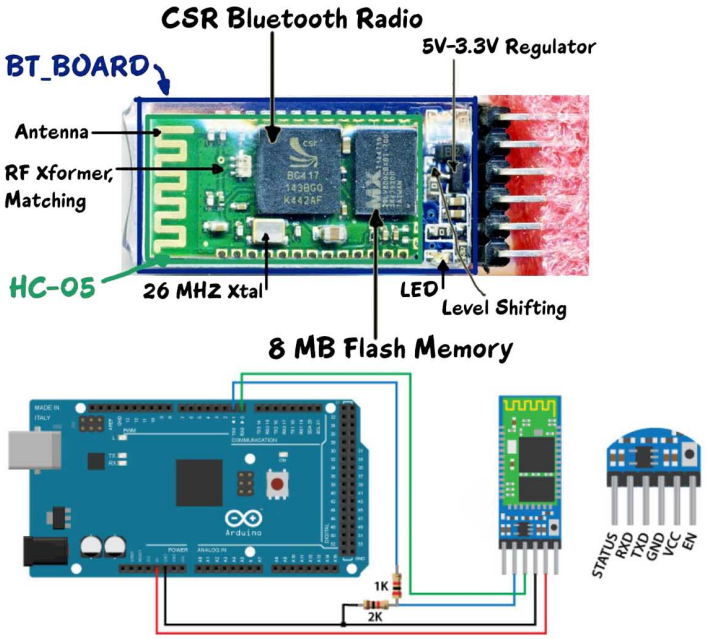


Figure 4.4: The circuit connecting pressure sensors to Arduino

4.2.2 Bluetooth Module

The wireless technology helps Arduino send data to this system and considering Arduino and sensors fixed on the chair, and wireless technology allow the different parts of this system communicate with each other without cable so that chair can move freely. There are several wireless technology used in Iot such as Wifi, ZigBee and Bluetooth. In this research, Bluetooth module HC05 as illustrated in Figure4.5 is used to send data via Bluetooth communication so that it can be independently set on any chair seat without using cable connecting to computers. The Bluetooth module can also help control Arduino and send data to not only computer but also smartphone. It can also create a data network for sharing

pressure sensor data. The possibility of avoiding a prolonged devices use on cross-platform can be discussed due to using Bluetooth module.



(Source: Arduino and HC-05 Bluetooth Module Tutorial [1])

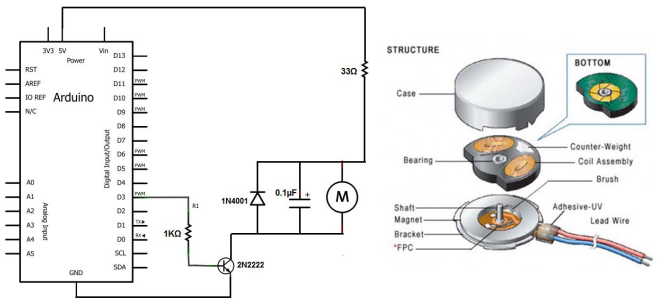
Figure 4.5: Bluetooth Module

4.2.3 Vibration Motor

The vibration motor is used to give users stimuli via feeling and in this project, a 2.7mm vibrating mini motor disc as illustrated in Figure4.6 is hidden on chair seat so that it can be hardly felt by users. This vibration motor is also connected to Arduino and serial connect with a 220Ω resistor. In the game environment and when users keep the same posture for over 15 minutes, the vibration motor works to notify users change a posture.

4.2.4 Data Analysis

The system receives two data every second from each sensor and save them to different matrices. It compares front-side data to back-side data and left-side data to right-side data and analyze users' sitting postures due to the ob-



(Source: How to Drive a Vibration Motor with Arduino [3])

Figure 4.6: Vibrating Mini Motor Disc

servation and data from experiments. The six sitting postures are leaning forward/backward/left/right, sitting straight and one leg over another.

For the six sitting posture evaluated in the experiment which will be discussed in more detail in chapter 5, sensed data showed that for sitting straight, the difference between front side and back side, left side and right side is smaller than 100:

$$|(F_{fr} + F_{br}) - (F_{fl} + F_{bl})| < 100$$

and

$$|(F_{fr} + F_{fl}) - (F_{br} + F_{bl})| < 100$$

For the posture of leaning forward, data of the front side is bigger than the back side and the difference is more than 200.

$$(F_{fr} + F_{fl}) - (F_{br} + F_{bl}) > 200$$

for leaning backward:

$$(F_{br} + F_{bl}) - (F_{fr} + F_{fl}) > 200$$

the posture of leaning left and leaning right, the difference between right side and left side is more than 500:

$$(F_{fr} + F_{br}) - (F_{fl} + F_{bl}) > 500$$

for leaning right:

$$(F_{fl} + F_{bl}) - (F_{fr} + F_{br}) > 500$$

for one leg over another one, the data of F_{fl} or F_{fr} turns to less than 500:

$$F_{fr} < 500$$

or

$$F_{fl} < 500$$

According to the observation, when they focus on their game, their main sitting posture is leaning forward. Leaning left or right is seldom for it is not easy for them to watch the screen and use keyboard or mouse controlling games. Sitting straight is not also not very common during the observation. For checking people's statues and judge if they are focus on their games or if they are in a relax situation. The system also compares the current data to previous data to check how much the sitting situation changed and duration of the change. For analyzing the moment that how much the data changes, it uses:

$$|F_p(t_{n+1}) - F_p(t_n)| > 200 \quad (p = fr, fl, br, bl)$$

to check the moment change. If the difference is bigger than 200, it checks if people had this substantial body movement lasting for more than 5 seconds. Then also check their next sitting statues or postures and compare it with the previous one.

The difference been chosen to classify users' sitting postures and stable situation such as 200 or 500 is based on the experiments in which participants with different gender and weight joined. The heaviest participant is 80kg and the lightest participant is 51kg. For the heaviest participant, the average data when he sit straight is about 900 and for the lightest participant, the data is about 800. Even though their weight is different from each other and the average data of each sensor when they sitting straight is also different, the difference between each side showing their sitting postures and situation is the same.

4.3 Software

The software part in this system is designed for analyzing data and sending the analysis result to hardware part and terminal part instructing what to do next. The software part uses Unity communicating with Arduino receiving data and analyzing data. Also, with the motion detect method in OpenCV and web camera to encourage people having physical activity breaks.

The raw sensor data received by Arduino is not very clear for understanding. The method to do data analysis is rather simple in this project for just marking

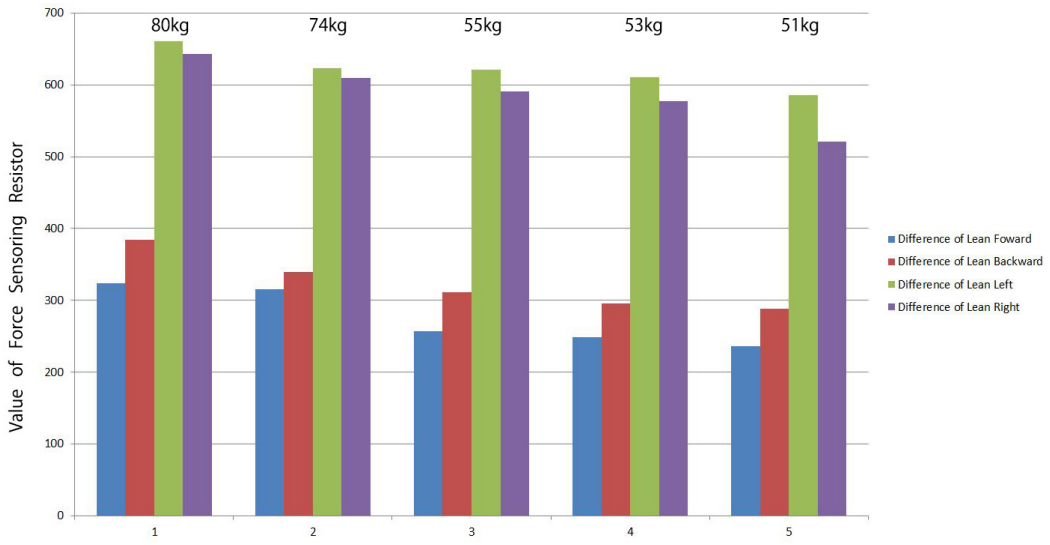


Figure 4.7: Average Difference of Different Participants

where the sitting center is. This system receives two data from each sensor for every second. It compares the data from front side to back side, left side to right side and current data to previous data to see the differences and changes, then according to the data analysis from experiments, it classifies the sitting posture and users' situation. When users concentrate on the screen, their sitting posture usually keeps stable and leaning forward.

Also, for learning if the timing a good timing for users to take a break, the system sends users messages via a window for asking if they accept this notification and using web camera for a physical activity break. Users' answers and the sitting data changes at that time will be saved for better methods of find the break point.

4.3.1 Motion Detect

This research uses web camera of computers to encourage users doing physical activity via motion detection. Web camera will be on when system asks users to take a break and the real-time stream video of users shown on the screen to The theory here is when background does not change, the moving objects can be extracted by using OpenCV tracking API. Then create a matrix to record the location of the moving objects and show its trajectory.

The motion detect method here firstly reading a video from web camera and then blur the frame to reduce high frequency noise so that it can concentrate on

the moving parts in the frame. Then it converts the frame to the LAB color space and captures the A channel. It catches two frames and compares them to find the difference and then uses Gaussian blur.

Next, converting frames into binary pictures and set eight as threshold number. If the number is bigger than eight, consider it as white, else as black. Using erode and dilate method to reduce noise. The contour area in this picture which is more than 10000 and bigger than others is the object this system wants to analyze as illustrated in Figure4.8. It gives a green frame to the object and gets the coordinate, weight and length of the object.

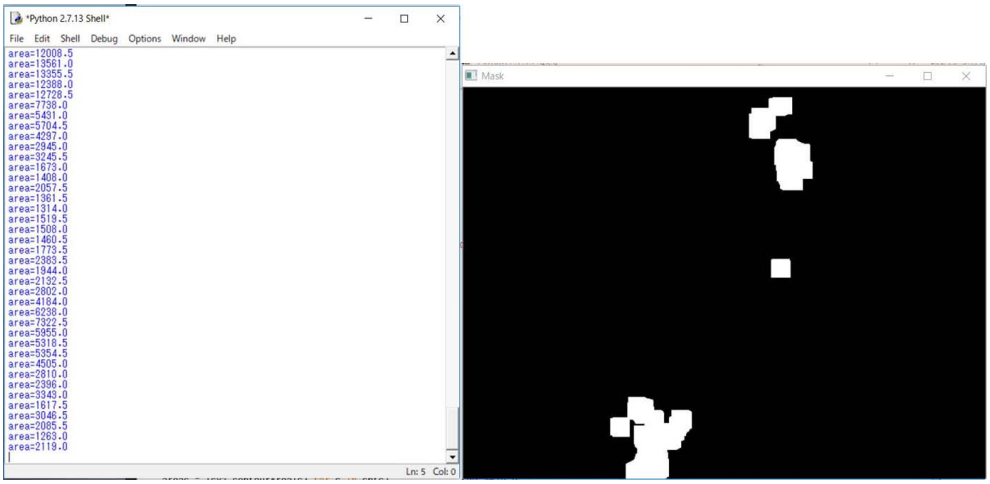


Figure 4.8: Contour Area of Moving Object

Then put the data into the pts queue which is used to save the location data showing the track of the moving object. The data in the pts queue are checked in turn and if the data in pts queue is more than the direction points, the system compare the x and y coordinate to analyze the direction. The track of the movement are drawn on the screen and the direction where people moved is also written by text as illustrated in Figure4.9.

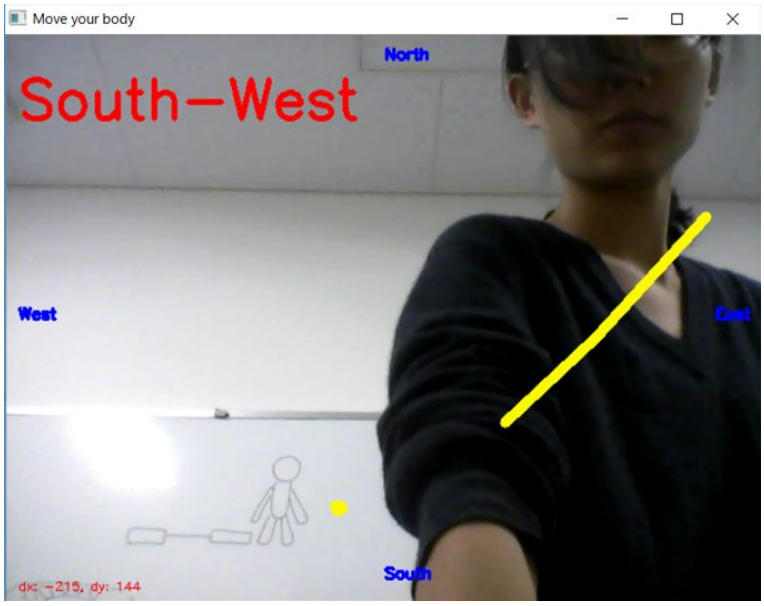


Figure 4.9: Using Web Camera Detecting Movement

Chapter 5
Evaluation

This research evaluates the system in two steps. First it demonstrates the possibility of using raw pressure sensor data to analyze users' situation and sitting time in controlled lab experiments. Then it tests the notification methods and notification timing for encouraging users taking physical activity breaks in different modes.

5.1 Measuring Users' Situation with Pressure Sensors

Participants sit on the chair and confront with a computer on the desk before them. They are asked to use different sitting postures such as leaning forward/ backward/ right/ left, sitting straight, and one leg over another as illustrated in Figure5.1.

Also, according to the max, average and min value of each participant, even though their height and weight are different, which can cause the different value from each sensor, the differences between each side follow the same pattern so that the algorithm can be used to general adults.

5.1.1 How to Classify Sitting Postures

The experiment asks participants to sit on the same chair using the sitting posture above in turn and keep the posture for 15 seconds. Every time they change a posture, they need to stand up to make all the sensor data goes to zero so that a boundary between different postures can be created. For checking reproducibility, every participant is asked to perform the same sitting postures for 20 times. All the data are analyzed and compared and for one participant, each participant's data are used as his or her data for help classifying their sitting posture.

Figure 5.1: Six Different Sitting Postures

Overall 5 healthy participants (2 males, 3 females, aged 23-26 years) joined in this experiment. Their height and weight are also taken into consideration. The first and last two seconds of each sitting posture data are not used for its instability when people just sit or ready for standing up. The following features are used for classification:

- Calculate the difference of sensor data on the front side and back side, left side and right side to find out where the sitting center is.
- Calculate the difference of the sensed data from the same sensor every minute to find out if users' sitting postures changed or not.
- Mean and RMS of four sensors combined.

For asking participants to sit on the same chair using the sitting posture above in turn and keep the posture for 15 seconds and gathering their data for classifying their sitting postures, here are the algorithm for classification. The data shown in the figure below using average data of one participant as illustrated in Figure5.2 5.3 5.4.

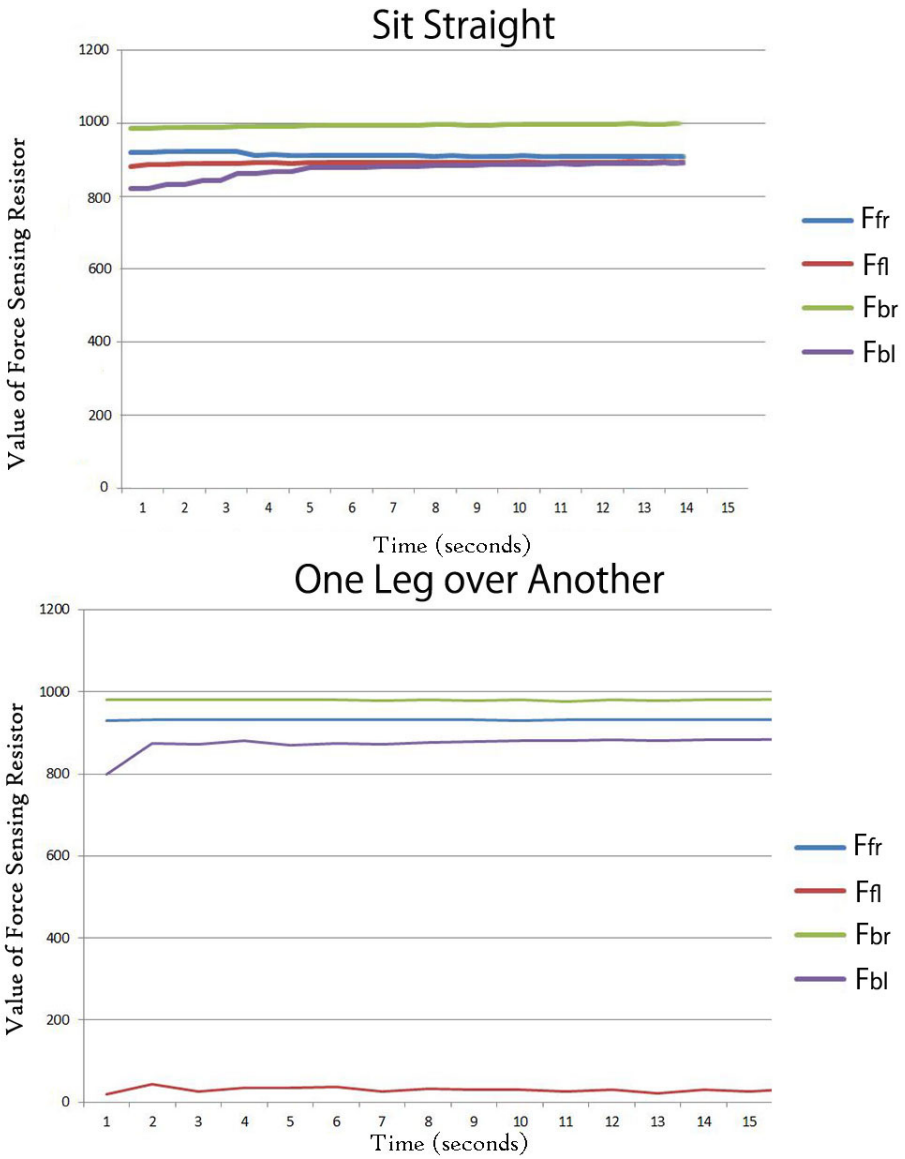


Figure 5.2: Data of Sit Straight and One Leg over Another

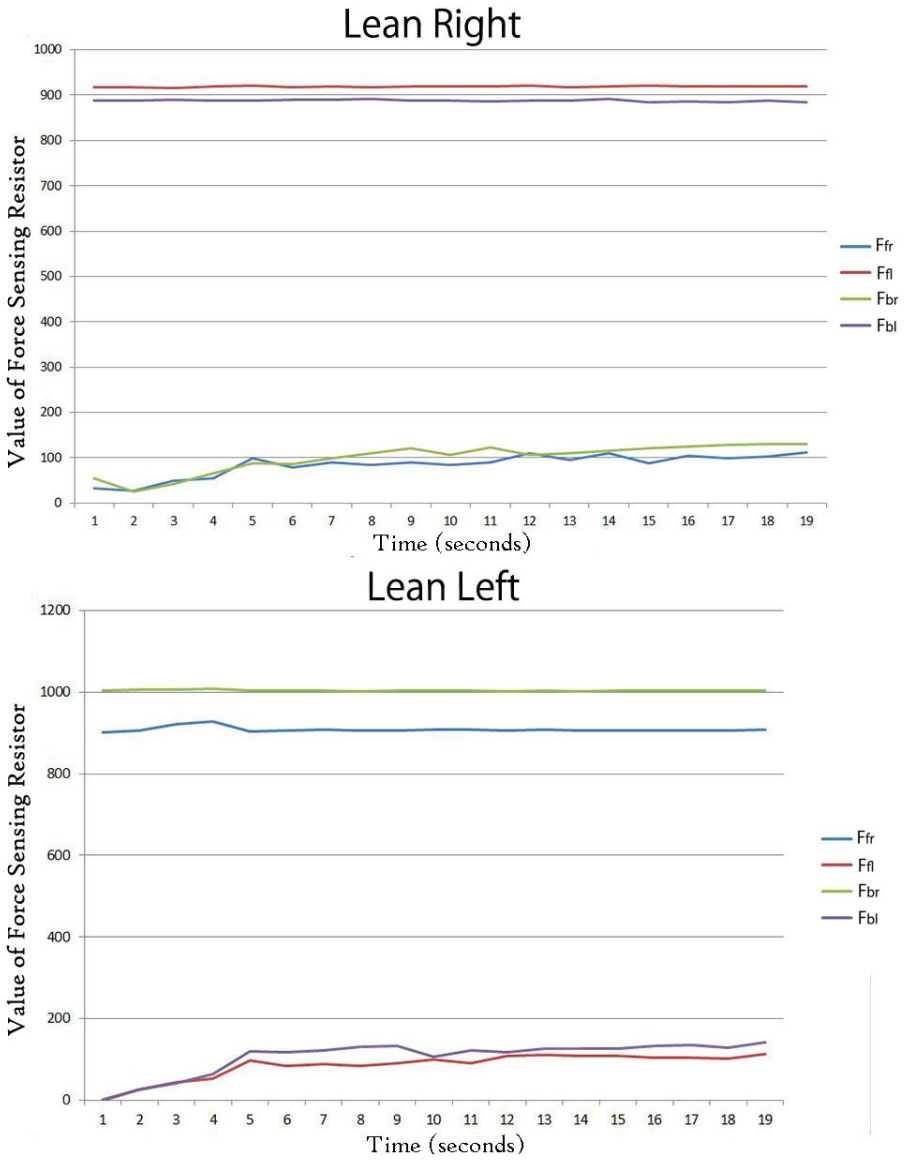


Figure 5.3: Data of Leaning Right and Left

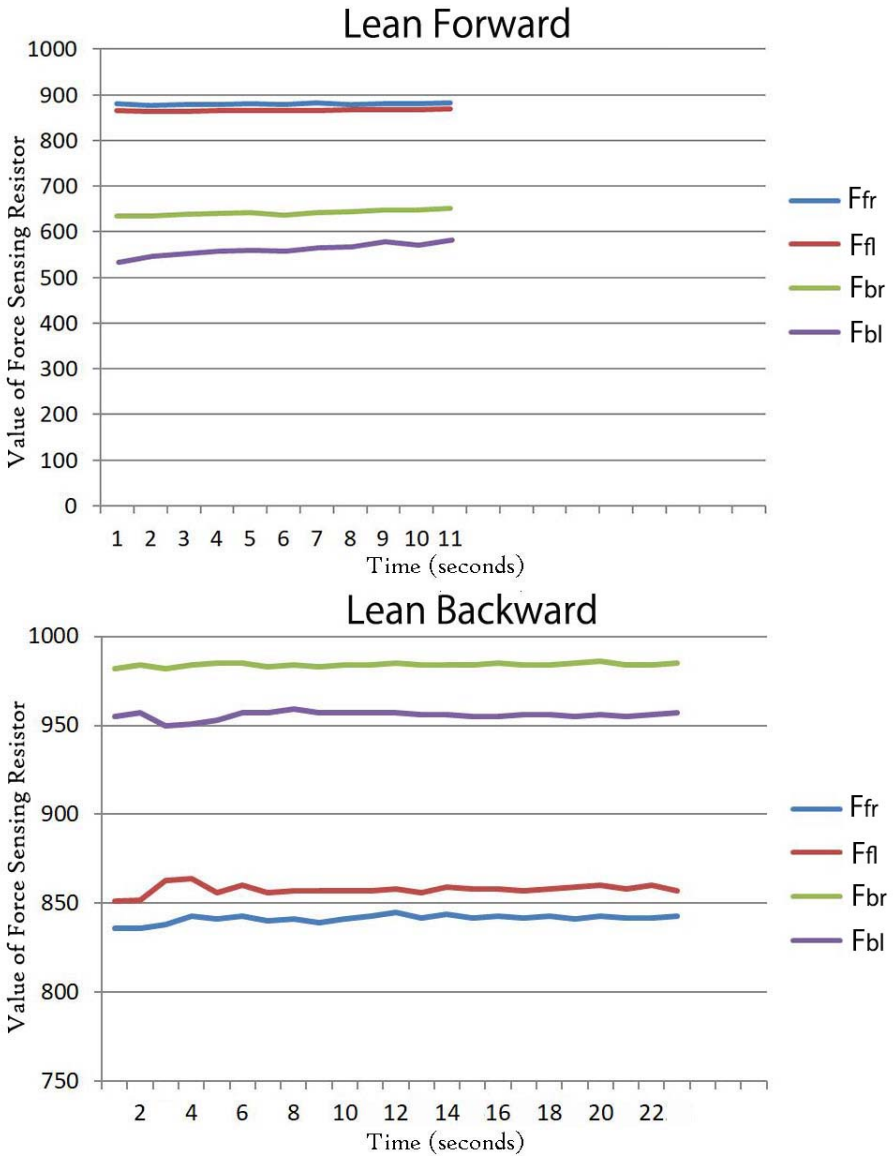


Figure 5.4: Data of Leaning Forward and Backward

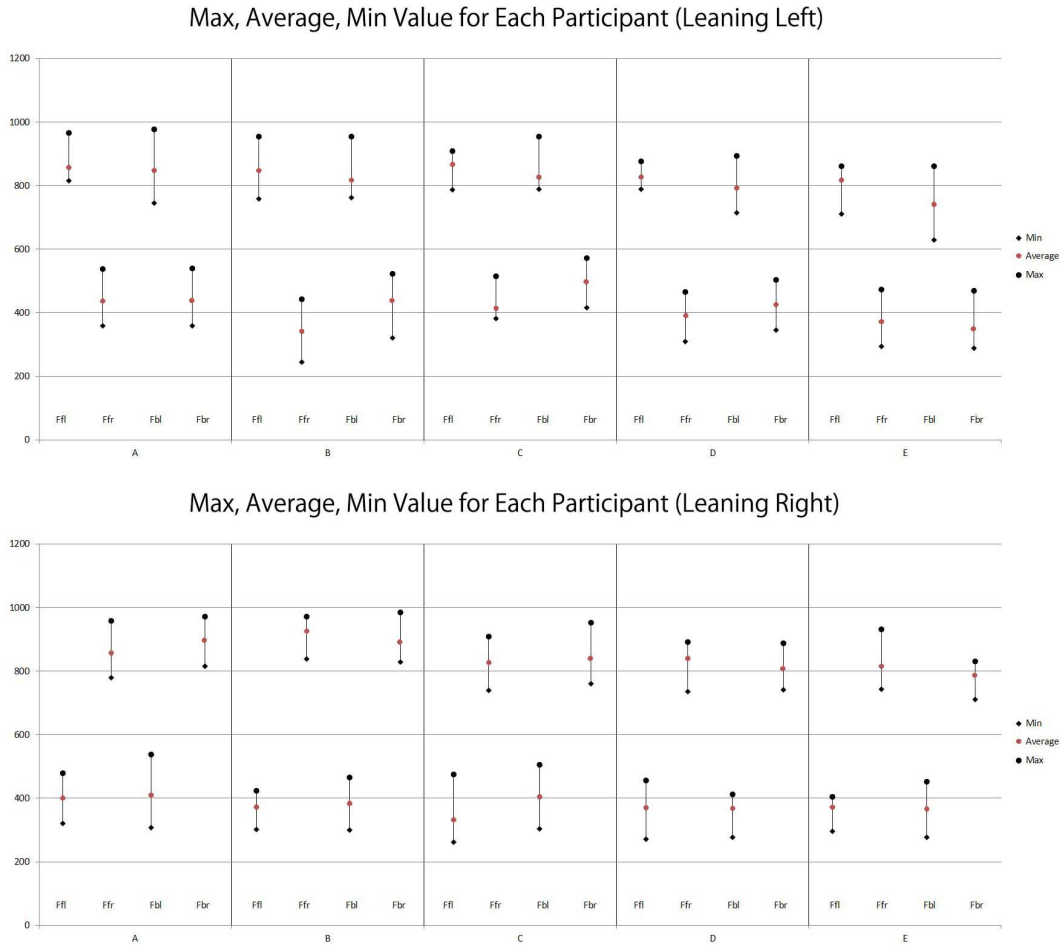


Figure 5.5: Max, Average and Min Value of each Participant:Leaning Right and Left

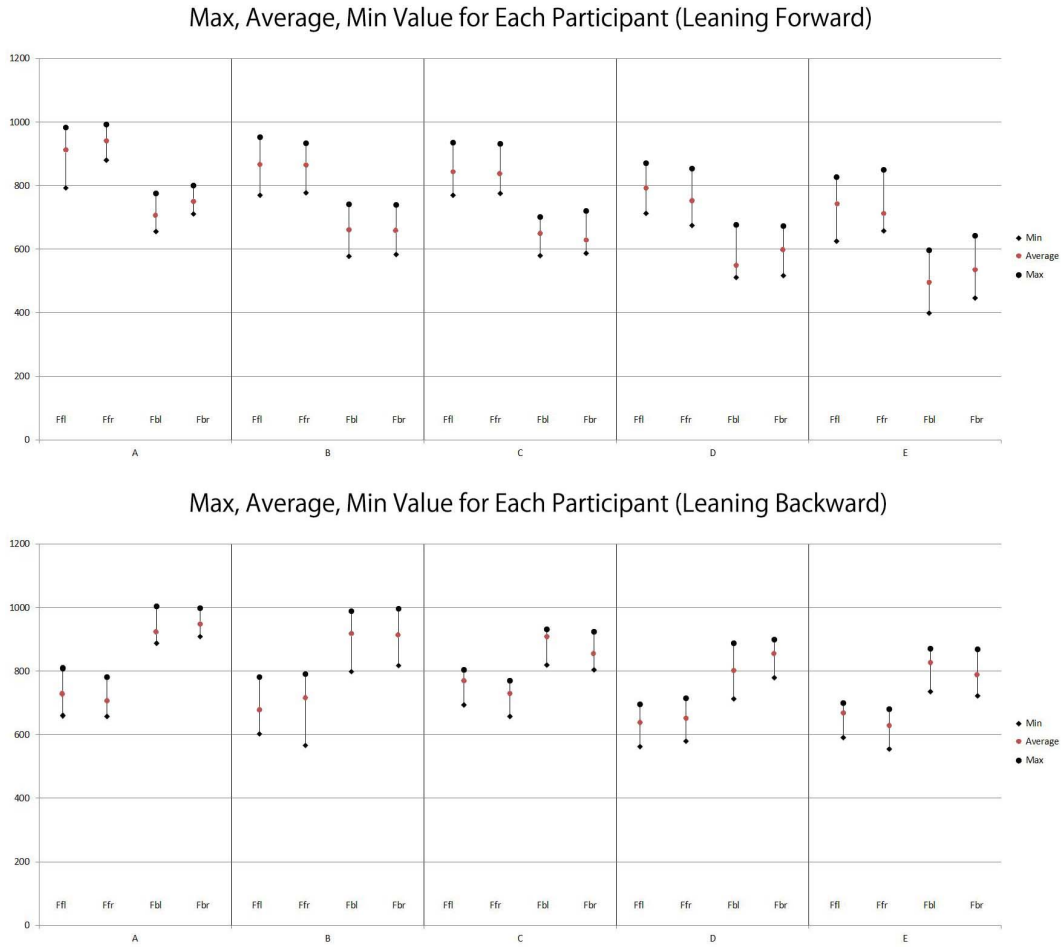


Figure 5.6: Max, Average and Min Value of each Participant:Leaning Forward and Backward

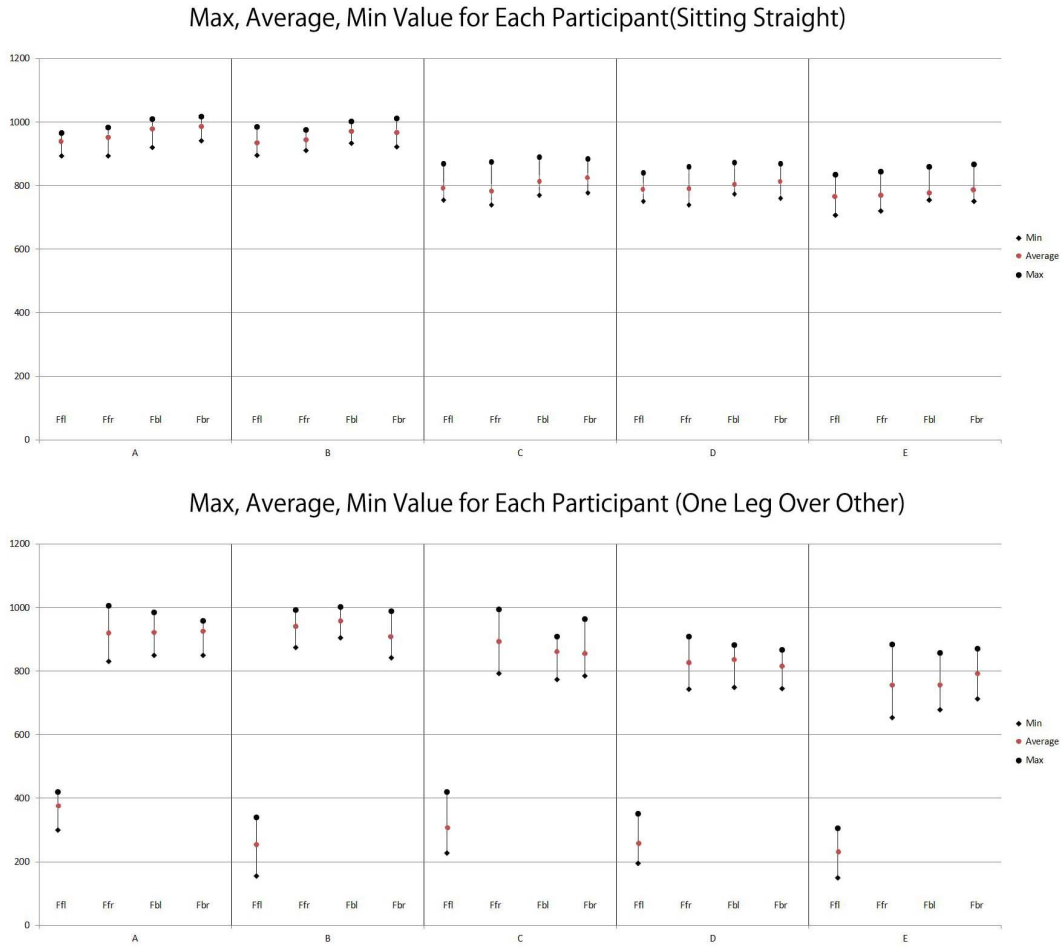


Figure 5.7: Max, Average and Min Value of each Participant:Sit Straight and One Leg over Another

Sitting Straight:

$$|(F_{fr} + F_{br}) - (F_{fl} + F_{bl})| < 100$$

and

$$|(F_{fr} + F_{fl}) - (F_{br} + F_{bl})| < 100$$

Leaning Forward:

$$(F_{fr} + F_{fl}) - (F_{br} + F_{bl}) > 200$$

Leaning Backward:

$$(F_{br} + F_{bl}) - (F_{fr} + F_{fl}) > 200$$

Leaning Left:

$$(F_{fr} + F_{br}) - (F_{fl} + F_{bl}) > 500$$

Leaning Right:

$$(F_{fl} + F_{bl}) - (F_{fr} + F_{br}) > 500$$

One Leg Over Another:

$$F_{fr} < 500$$

or

$$F_{fl} < 500$$

5.1.2 Assessment of Classification

The difference between front side and back side can be not very stable at this situation for people moved a lot when they lean left or right so that they may just mainly press one sensor, however, this situation can still be distinguished for the huge difference between its right-side data and left-side data. Considering the average value of each sensed data from each sensor of other posture is more than 700, this can be the feature to distinguish this kind of posture. Then asking participants to sit in different postures without telling the system and using the regular pattern concluded in previous experiments to classify their 6 sitting postures. For every participants doing the 6 different postures for 20 timesthe accuracy for sitting straight is 76%for lean forward is 79%, for lean backward is 81%, for lean left is 82%, for lean right is 84% and for one leg over another is 89%. The reproductibility also worked well. The raw sensed data showed the feature of different sitting postures.

5.2 Timing of Notification

The hypothesis of notification timing is based on the video observation of people who using computer playing games and work. Because the timing of notification is considered as an important factor for users involving in and accepting the notifications, the theory here is to find a breakpoint when users are not in a high degree of mental concentration according to the observation and previous researches [20], users' mental situation can be reflected on their behaviors such as sitting postures or the change of their sitting postures.

5.2.1 Video Observation

The observation based on video recorded both users' faces and the screen on which the process of games can be observed. For each participant, they are asked to play the same game for 3 hours. It shows that when people focus on the game, they may have different postures but each of they keeps that posture for a quite long time. For the observation of one of the participant, he remained almost the same posture for more than 30 minutes and during this process, according to the data, the changes on each sensor is not very big. When he played the game for 35 minutes, he seems lost his focus and decided to take a brain rest and still reminded sitting. He chose to use his smart phone for a brain rest, for this period of time, his sitting posture changed a lot and for a quite long period and because his sitting posture became very casual during the rest time, he even did not press on each sensor and the changes on each sensor is obvious. According to the observation, when people who play game lose their concentration and took a brain rest, his body movement is more intense and orderless and usually more than 5 seconds(Figure 5.8), which can be used as a feature to help find out the timing for notification. There would have slight movements during their concentrating time but the duration is quite short, according to the observation recorded by the video, it is less than 3 seconds and it usually a simple swing from front side to back side and they may stay in the back side for a long time.

5.2.2 How to Measure Sitting Situation

According to the video observation and the data recorded by sensors, it uses

$$|F_p(t_{n+1}) - F_p(t_p)| > 200, (p = fl, fr, bl, br)$$

Figure 5.8: Observation of People Who Play Games

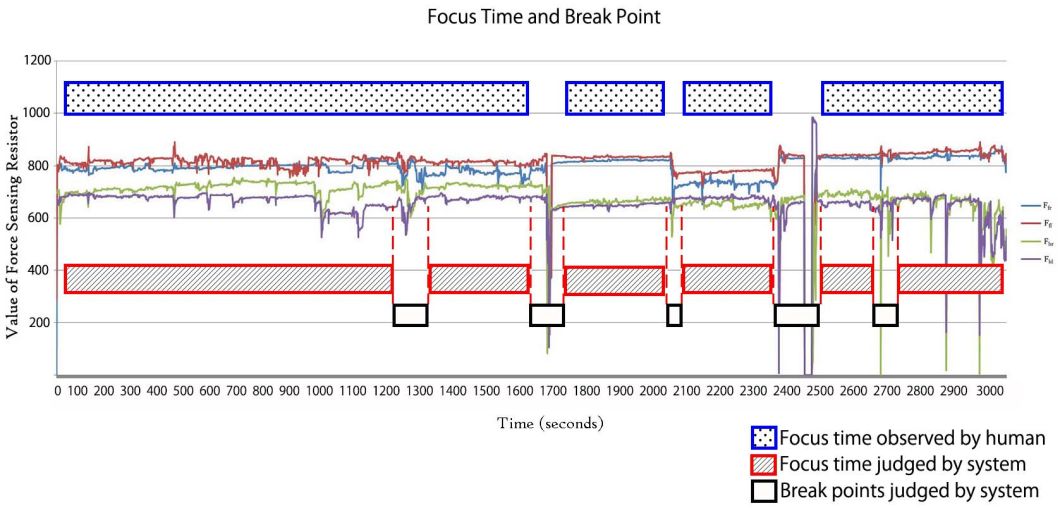


Figure 5.9: Focusing Time and Break Point Judged by System

to check users' situation and also check users' sitting postures. The condition below will be judged by system as a point for giving notification.

- User in a quite unstable situation and this situation stays more than 5 seconds.
- The system judges that user is leaving the chair.
- User keeps leaning backward for more than 15 minutes.

People who played the game for more than 50 minutes, the system found 5 possible break points according to the sensed data and give notification at the breakpoint. It turns out that in five break points, four are confirmed to be the real break points. One is not a real break point for user just adjust his sitting posture for better concentration. The participant accept three of them as illustrated in Figure5.9.

For not receipting all the notification, according to the participants who played games for 3 hours and get notifications from the system, there are several reasons they do not take the notification, for some of them, even though one session of the game is over, they do not want to take a rest for expecting to get higher scores in next session. Taking a break before two sessions, their game feeling will get hurt. There are several possibilities for users when they get the notification. In the evaluation parts, using camera to record users' reactions and also ask they to say something when they receive the notifications for example, annoying or one more game, so that their reason for not taking break can be easily understand. Also, according to their reactions, is this timing a reasonable timing for giving notification can be judged. If users received notification and decided not to take a break, there will also be some options this system will take to help users taking break. For user who feel like this notification is annoying, when system find out another notification point, it will choose to wait and not give notification at every break point and choose the break point more carefully, for example, when the difference between each side getting bigger than usual or the lasting time is longer than usual, it will give notification to try again. The total notification times is 35 during the additional experiment, and the total acceptance is 16 times, the total game time is 20 hours. Participants find the notification annoying is total 5 times and they want to play one more game before taking a rest is total 9 times. The system mistake is 5 times. It is still hard to find out the exact best timing for every one for notifying them taking a break. Each participant feel different when they

get notifications. For each different individual, their preference setting should be arranged. According to the short interview after this experiment, people who said annoying prefer this system not notify him every time it find he moves a lot. For people who want to play one more game before rest, they hope that system give more notification so that they can be more distracted from the game and actually take some break.

When their sitting center is on front side or when they keeps the same posture for a long period of time, the system judges the situation as users concentrating and does not give notification. According to the observation, when users lose concentration, most of them choose to take a brain rest or go to toilet or go for some drink. Between their focus time and their brain break period, there are some action they take. For example, stretching, moving their body for adjusting their sitting posture, playing with smart phones or talking to others. All these activities is with substantial body movements during a quite long period which is considered as more than 5 seconds. For checking the movement, it compares the current data to previous data. If the difference is bigger than 200, it also check if the duration of the change is more than 5 seconds. When the data shows that users' sitting posture is quite casual or their sitting postures changes more than 5 seconds, the system judges that the users is in a relax situation and send notification to encourage them taking a physical activity break. When the pressure sensors says that user leaves their chair, it is also considered as a timing to give notification. For gathering more information to help this system doing better, before using web camera guiding people doing physical actions, a message showed on a window pops up to ask if users want to take a break now or not.

5.2.3 Assessment of Notification Timing

For verifying how the sensed data can find out the timing of notification and the acceptance of users to taking a break. Five participants who like playing games with the same genre are asked to play the games they like, which are action games needs users using keyboard to control a character in the game move, jump or squat. The data are recorded for analyzing and also, according to their sitting information, message is given to ask if they want to take a rest when the system judges that they are lose interesting and not very focus on the game and taking a brain rest. According the the observation, five participants all take brain rest during their playing time such as stop to play their smart phones or to talk to others, which causes the change of sensed data. For playing game, they have less

body movement and frequent mouse and keyboard movements, which is hardly detected by pressure sensors setting on chair, so that the data of sensor keeps a relative stable situation. For the period they stop to have a brain rest, their body movement is very obvious and the changes of data is quite obvious for a quite long period. When they take brain rest, even though they do not concentrate on their games any more, they hardly stand up for a physical activity break. Most of they spend like 10 minutes playing with their smart phones or talking with their friends and then they go back for their games. The periods of time when they take a brain rest is considered as a good timing for giving notification. The corresponding sensed data help system do the judgment for giving notifications or not. Comparing with the observation recorded by the camera, their activities and their status can be also known. One participant play the games more than three hours a day and the average duration of other participants play games more than one hour.

Table 5.1: States and Notification Acceptance

Status	Activities	Data	Accuracy(times)	Acceptance(times)
play game	seldom body movement	most leaning forward, stable	18(Total:20)	3(total:20)
breakpoint before brain rest	much body movement in a short period	unstable	39(total:45)	31(Total:45)
leave chair	no pressure	no body on chair	15(total:15)	13(Total:15)

The acceptance of encouraging people taking their physical activity break works well according to the interview of these participants. Their feedback showed that the notification timing based on sensed data is more acceptable.

5.3 Methods of Notification

Three different stimulus in this research are evaluated, pop up windows, vibration and body movement guidance. These three stimulus combined together to notify users. The first combination is pop-up window and body movement guide using web camera. Participants are asked to play games and these three stimulus are used for different situations. Pop up windows showed on screen used to ask participants if they want to take a break or not, if users choose yes, the web camera

turns on and takes up the whole screen.

The whole screen is divided into four equal divisions, and directions are shown on the screen: east, west, north and south. Then there is guidance point shows on the screen asking users to move their body. For example, if the point shows on the east-north area, users need to move their hand or part of their body to that direction. The second one is vibration, the vibration motor is set on seat and when the time comes, it vibrates for notifying users. Only when users stand up for more than one minutes, the vibration will stop. The third one is just use pop up windows to notify users and users can choose accept or ignore the notification. The forth one uses pop up window and vibration, the pop up window shows first to notify people that they may take a break one minute later, the vibration motor will start work after one minute.

Participants are asked about their feedback about these four different combinations. The motion detection method is highly praised by participants and they think this method can help and do check their if they moved or not. Also, when they focus on game or work, seeing their faces on the screen helps them raise their self-awareness for breaking up the current sitting habit. Their feedback shows that even though they know that standing up, having physical activities or changing sitting postures as much as often can help them improve physical wellness, it is still hard for them to take actions spontaneously. This motion detection method do help them rethink of their device use and current lifestyle. The vibration part is a little bit annoying to them, however works well especially when they play games. Because during the game time, the feelings of seeing and hearing are kind of blocked and the feeling of touching is more sensitive and since nothing shows on the screen, they will not get disturbed while playing games.

Chapter 6
Conclusion and Future Works

This thesis explores the possibility of using sensed data to help analyze and detect users' situations in a cheap and easy way. According to users' different situations reflected on these data and the mode they chose, the system gives notifications in different ways with different stimulus. Also, the system tries to find a breakpoint to notify people in order to avoiding distracting and annoying people. The hypothesis here based on the observation of game player and people use computer working. When they concentrate on the screen, they almost keep the same sitting posture and lean forward for seeing the screen more clear. When they lose concentration, there are usually some activities they would take, such as picking up their smart phone or just adjust their sitting posture.

6.1 Discussion

Traditional way of giving notification has low effectiveness and sometimes can aggravate cognitive load to users for its showing up in a wrong timing. This thesis tries to get information of users from four simple and cheap film pressure sensor and analyze their sitting situations and find a better timing giving notification rather than letting users setting reminder alarm. There are four sensors set on four different side of the seat pan to gather data. The system receives 2 data for one second from each sensor. Every time system receives data, it compares the sum of front side and back side, the left side and right side to classify users' posture and sitting center. It also compares the current data to the previous one to check how much it changed. According to the data analysis, the system decides to notify users take a break or change their sitting posture and avoids disturbing users when users are concentrate, especially when they works.

The experiments also shows that this kind of cheap and simple sensors can roughly detect users sitting postures and the duration of not changing their pos-

tures. The sensor is quite sensitive about people's movement which can also cause some misjudgments. The data analysis part tries to keep the sensibility of detecting users' posture change and also tries to reduce the misjudgments via adjusting the determine conditions. Further, using sensed data of people's sitting information as the input to notify people can protect people's privacy comparing the way using camera, key strokes or mouse click as input.

Also, according to participants' feedback, their attitude for being notified via using vibration motor and web camera is quite positive. For the vibration part, they think during the game time, vibration is a quite good method for notifying them change their sitting posture rather than pop-up notification or sound notification because when they play games, their visual feeling and hearing are weakened for concentrating on the screen and sound from the game. For using web camera to guide them doing body movement, they said it may not work every time, but looking at their faces showing on the screen can make them realize more about themselves, even though following the guidance and moving their body will cost them more time to get used. However, according to the feedback, comparing to just giving pop-up or sound notifications, using web camera and motion detect for notification is more interesting and efficient for them to get engaged.

Further, the motion detect method to encourage users taking a physical activity break and its possibility of helping people raise a new habit of standing up and moving around as much as possible during their prolonged sitting time and breaking up their sedentary lifestyle is also investigated in this research via interviewing participants and other computer users. This Also, the stability of the film pressure sensors

6.2 Contribution and Future Works

In this thesis, a sensed data based notification system is created and tested to encourage people do more physical activity break. It mainly uses sensed data from pressure sensors as input to detect users' sitting situation and according to data analysis deciding how to notify people take a physical activity break or just move their body for avoiding keeping one same sitting posture for a long time. In this thesis, six usual sitting posture are tested. Five participants are asked to sit in different postures lasting 15 seconds and 20 times for each one. The data are used to set a standard of classifying their posture. This thesis investigates a rather proper timing for notifying people who play games to take a physical activity

break via observation. The notification methods used in this system combines visual guidance and vibration are also tested to see how people accept them. For future works, this system tries use more sensors to gather data from users' such as pulse sensor and wearable device like smart watch to build a information network for measuring users' situation more accurately. Also, developing a cross-platform system for not just avoiding a prolonged computer using, but also help people reduce their sedentary time.

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