LOW-COST SMART PILLOW

By

Cheah Chun Hou

A REPORT

SUBMITTED TO

Universiti Tunku Abdul Rahman

in partial fulfillment of the requirements

for the degree of

BACHELOR OF INFORMATION TECHNOLOGY (HONS)

COMPUTER ENGINEERING

Faculty of Information and Communication Technology
(Perak Campus)

MAY 2018

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I declare that this report entitled "**LOW-COST SMART PILLOW**" is my own work except as cited in the references. The report has not been accepted for any degree and is not being submitted concurrently in candidature for any degree or other award.

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ACKNOWLEDGEMENTS

I would like to express my sincere gratitude and appreciation to my supervisor, Mr Teoh Shen Khang who has given me this great opportunity to develop and designing the Low-Cost Smart Pillow to help improve sleep quality among the users. He did a great job in giving me some new ideas for this final year project. Besides that, this project is my first project developed using the Arduino board with custom Arduino shield and Raspberry Pi 3.

To a very important and special person in my life, JC Chai, thanks for her love, patience, endless support and take well care of me during the tough times. Not only that, I need thanks to my friends and my family members as well. With the help and opinion provided by my friends did save me a lot of time during the development of this project. Finally, I felt thankful because of the encouragement and constant support and from my beloved family.

ABSTRACT

This final year project is about designed and develops a Low-Cost Smart Pillow using an Arduino Uno (a microcontroller) and Raspberry Pi (small single-board computers). The Low-Cost Smart Pillow is built according to collect the amount of user toss and turn during sleep and some of the factor that can affect sleeping quality. Not only that, the Low-Cost Smart Pillow is connected to the IoT network, thanks to the IoT platform provider – Ubidots. Meaning that all the information is storing in the cloud. The user can view it anytime everywhere as long as the internet is connected. Nowadays, insomnia is quite common for adult, the main purpose of this Low-Cost Smart Pillow is to help user trace back what is their sleeping quality and what factor that actually affect their sleeping quality. Smart Pillow can be found commonly in the market nowadays, but mostly, there are come with the high price. Because of this, these smart pillows are not affordable for some of the people. Hence, a specially designed Low-Cost Smart Pillow is needed to provide the second option to users and let user more understand and monitor his/her sleeping quality and improve it. A Low-Cost Smart Pillow is designated in this research to help the insomnia user improve their sleep quality and cost saving.

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LIST OF ABBREVIATIONS

GUI	Graphical User Interface
IDE	Integrated development environment
UART	Universal asynchronous receiver-transmitter
FSR	Force sensitive resistor
PC	Personal Computer
PCB	Printed Circuit Board
ADC	Analog to Digital Converter
LUX	Luminous Flux Per Unit Area
USB	Universal Serial Bus
IoT	Internet of Things
CAM	Computer-aided Manufacturing
UID	Unique Identifiers
MMC	MultiMediaCard

CHAPTER 1: INTRODUCTION

1.1 Background Information

1.1.1 What is Sleep?

Sleep, a resting state in which our body is not active and the mind is insensible. Sleep is the act of slumbering. At this time, our body systems will refresh themselves. English Dictionary defined sleep as a state of body and mind which relapse for several hours every night, the eyes closed, the body muscles relaxed, and the nervous system is idle.

As we known, everyone need sleep to continue our regular schedules. Sleep is crucial to all the living individuals. In our whole life, we'll spend about 36% to sleep. If the individuals getting enough quality sleep at the right times, it can help to protect the physical and mental health and also the safety of an individual. The quality of sleep will directly affect our physical and mental health and the quality of our life, including the productivity, heart and brain health, imagination, immune system, vigour, and even a weight (Smith, Robinson and Segal, 2017). At the sleeping stage, it helps in repairing and maintenance of body cell and network level, endocrine function, energy conservation, environmental and brain adaptation and also help in learning ability.

Sleep plays an important role in the case of brain function. While we're sleeping, our brain stays busy, it's working to form the pathways that necessary for learning and memorizing. For this reason, the efficiency of the brain function will increase. Research has shown that sleep will enhance our learning and problem-solving skills and aid in making decisions. In the same way, sleep is also essential for the maintenance of physical health. For example, it involved in repairing the body cells, heart and blood vessels. Sleep deficiency will cause the increasing of the risk of heart disease, high blood pressure and stroke. Furthermore, it also helps to maintain the balance of hormones in the body. For instance, ghrelin or leptin (hormones that will make us feel hungry or full). Lack of sleep causes the increasing of ghrelin level and the leptin level will decrease. In fact, this explains the link between inadequate sleep and obesity. Besides, sleep also supports growth and developments. If our body involved in deep sleep situation, it will trigger our body to release the growth-promoting hormones that will boost the muscle mass and help to repair the cells and tissues in the body. The immune system of our body will become stronger and will be more easily to defence the infection if we're getting enough of sleep.

Without getting enough hours of recharge sleep, physical changes will occur in the brain. We will feel fatigue throughout the whole day and won't be able to perform well at a level that closes to our true potential. Moreover, we also pay attention and can't focus or respond rapidly. Lack of sleep will cause the increase in the risk of obesity, infections, cardiovascular disease, and diabetes.

According to (Thomas, 2017), there are two mechanisms by which the body becomes sleepy or aware of its need to sleep. Firstly, is the adenosine. Adenosine is a metabolite that results from cellular processes. It utilizes the natural build-up of the neurotransmitter chemical adenosine in blood. When the physiological activity is increasing, the adenosine levels in the bloodstream will also rise. Thus, it will regulate the sleep-wake cycle when reaches the forebrain region. When we felt fatigue, people usually go to sleep. When we're sleeping, mental and bodily activity are at their lowest stage. Therefore, there is less energy for the adenosine production. Adequate of sleep will increase back the adenosine to a normal level and our body will feel energetic and wakefulness. Next is the biological clock (circadian rhythm). It acts as the timekeeper in the brain and is the internal system that can regulate the levels of sleepiness and wakefulness over 24-hours for an individual. It can be affected by light or darkness. This system is depending on different people, which means that for some people their clock might rewind earlier.

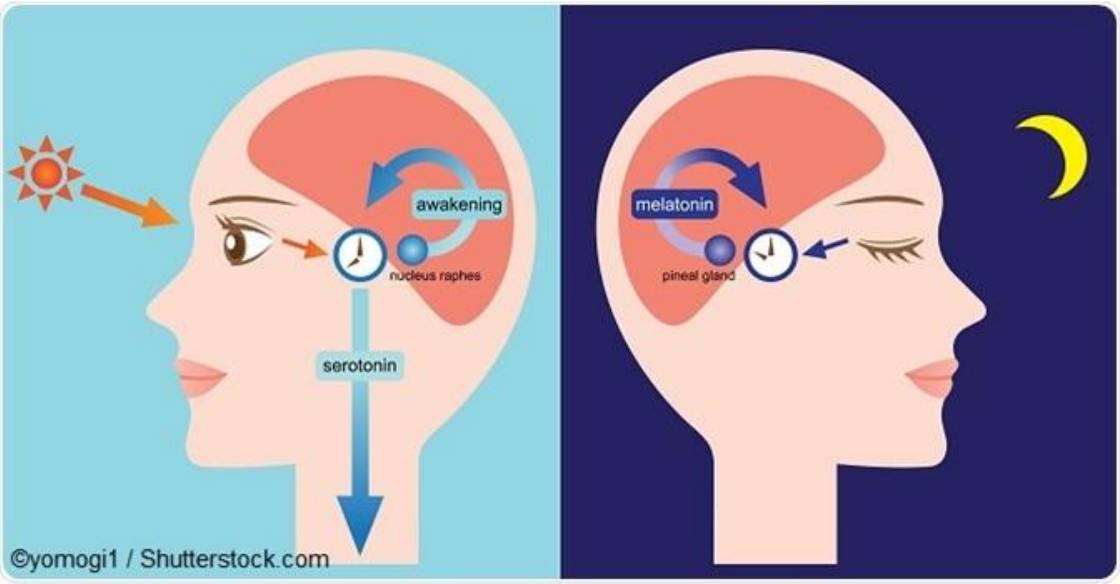

Figure 1.1.1: The two mechanisms by which the body becomes sleepy or aware (Thomas, 2017).

1.1.2 Negative Impact of Disturbance Sleep

The information of the human body is the central nervous system. In fact, sleep is a must to keep their central nervous system functioning properly. However, when others disturb their sleep, their body will get disrupted. Disturbance of sleep makes their brain cannot perform its duties due to the brain is exhausted. Besides, the signals in their body may also come with a postponement, reducing the coordination skills. It will also lead to a reduction in mental aptitudes and emotional status. Then, they may feel more impatient or prone to mood swings. The decision-making processes and creativity will be compromised as well. A lack of sleep can trigger psychological risks which are suicidal thoughts, depression paranoia, impulsive behaviour and others.

Furthermore, the processes at which keep their heart and blood vessels are affected by sleep there are including inflammation levels, blood sugar and blood pressure. It also plays a very important task in their body’s ability to rebuild and repair heart and blood vessels. Cardiovascular disease is normally found in those people who do not get enough sleep.

Our immune system produces protective, infection-fighting substances like cytokines while they sleep. Cytokines are used to fight foreign intruders such as viruses and bacteria. The cytokines can help they sleep, providing their immune system more power to secure their body against illness. The disturbance sleep prevents their immune system building the defensive wall. Their body may not be able to fight back intruders if they do not get enough sleep. Our recovery from illness will decrease as well. The risk of for chronical illness such as diabetes and heart disease is normally caused by the long-term of sleep disturbance.

After a few nights of lost sleep, most of the people will have experienced sallow skin and puffy eyes. However, lacklustre skin, fine lines and dark circles under our eyes will cause by chronic sleep loss. This is because their body releases more of the stress hormone cortisol when they do not get enough sleep. The cortisol can break down skin collagen which is the protein that keeps their skin elastic and smooth when in excess amounts. Serious of disturbance sleep causes their body to release too little human growth hormone. The human growth hormone promotes growth when they are young which it helps to increase muscle mass, thicken skin and strength bones.

According to a 2004 study, people who often get disturbance of sleep were almost 30% more likely to become obese than those who sleep 7 hours to 9 hours. Sleep loss not only appear to stimulate appetite, it can also stimulate cravings for high-carbohydrate, high-fat foods. Therefore, the weight loss programs can be classified by ongoing studies to be a standard part.

1.1.3 Factors Affecting Sleep

The primary factor that can affect sleep is light (Epstein and Amira, 2007). It makes they difficult to fall asleep to affecting the timing of their internal clock and it alters they preferred time to sleep. The specialized "light sensitive" cells in the retina of our eyes detect light that will influence our internal clock. These cells will tell the brain whether it is daytime or nighttime and their sleep time is set accordingly. Other than that, exposure to light in late evening will postpone their internal clock and make they more difficult to fall asleep at night. Exposure to light in the midnight can have more serious effects, it causes their internal clock to be reset and make it tough to return to sleep.

Secondly, sleep problems will occur when they exposure to light changes caused by a shift in work schedule or travel overseas across time zones. The internal clock affects their ability to sleep under normal circumstances. For example, individuals who work the night shift or travel across time zones will have two symptoms. First, they will feel super sleepy during the time when their internal clock tells them to sleep. Second, they feel hard to fall asleep when they are trying to sleep outside their internal phase. This factor should be seen by those who work a night shift for example airline pilot, nurses and other public safety workers.

Sleep quality and quantity can be greatly affected by the sleep environment. The light, noise and temperature that made up the sleep environment. Light intensity too high at night can alter their internal clock. It will make us hard to get a restful sleep. Therefore, to minimize this effect warm light in bathrooms and lobbies can be used. Research shows that the perfect temperature during sleeping differs widely among individuals, there is actually no ideal room temperature for a better sleep. But, the extreme temperature in sleeping environments will reduce the sleep quality. REM sleep is more sensitive to temperature-related disruption.

Lastly, Humidity in the bedroom is the important factor that can affect sleep. Humidity is important for their health. A normal humidity level is needed for feeling comfortable. Balancing humidity can be a complicated way, dry winter air can cause irritated throats, dry skin, and makes flu, cold and other viruses inside the bedroom. But, high humidity in the bedroom can make huge problems and even harmfully affect your health. Microorganisms that active in humid conditions are of special attention as they can help cause asthmatic and allergies conditions. Therefore, humidity levels of the bedroom should be about range 30-50%, with the ideal hovering at 45 percent (Carey, 2011).

1.1.4 Internet of Things (IoT)

The IoT, or internet of things, is a system of interconnected computing devices, digital and mechanical machines, objects, people and animals or that are equipped with unique identifiers (UIDs) and it has the capability to transmit information over a network without requiring or human-to-computer or human-to-human interaction. The Internet of Things (IoT) is using network sensors in physical devices to allow for control and remote monitoring. This technology has gained huge traction in several areas like manufacturing, consumer goods, retail, healthcare, banking etc. In this final year project, Internet of Things (IoT) system will be to used so that the data of Low-Cost Smart Pillow can store it on the cloud. The user can view it anytime everywhere as long as connected to the internet. The Figure 1.1.2 below is showing the device connected Internet of Things (IoT) worldwide from 2015 to 2025 (in billions).

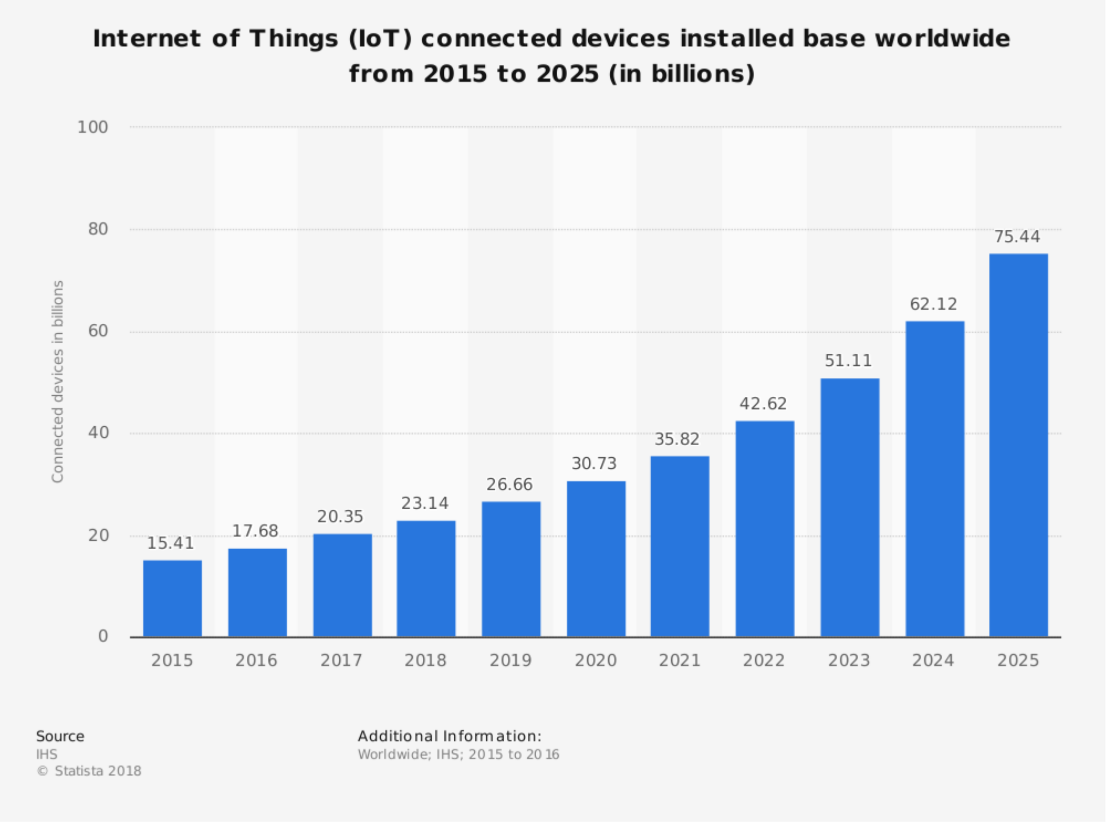

Figure 1.1.2: Device connected Internet of Things (IoT) worldwide from 2015 to 2025 (in billions)

1.1.5 What is Smart Pillow?

What is a smart pillow? If a person suffers from snoring, the smart pillow can make a huge difference. Actually, they can enjoy a better night's sleep and reduce snoring during the night if they correct chosen anti-snoring pillow (Walton, 2017). This can evidence invaluable to them and to anyone else sharing their room. The Smart Pillow is designed to increase human sleeping quality. The Smart pillow can be also defined as an electronic pillow which consists of different type of functions. Firstly, the Smart Pillow is capable to stop snoring by identifying the snoring and vibrates gently to adjust user sleep position without waking them up. This is because the Smart Pillow offers with an integrated microphone, which will identify snoring event through the whole night. Smart Pillow also contains a sleep analysis feature which will function or works by linking to your smartphone via the apps. Thus, your sleeping data and snore score will be detected during the night.

Besides, it's also providing Streams Music and Audio. The Smart Pillow can play sleep music wirelessly and other audio even video from the popular application without troubling your sleep partner. Hence, through this Smart Pillow, you are able to play your favourite music to help you to get sleep quickly. For instance, classical music, relaxing piano music and others. On the other hand, it's also able to function as a sleep tracker through measuring the sleep motion and snoring decibel, which resulting in a Sleep Score and generate a full daily report of sleep quality and relaxation. Apart from that, instead of using an alarm clock, Smart Pillow is able to set an alarm clock and it will vibrate gently and play some warm music to welcome user welcome and enjoy the all new days for increased morning energy. Lastly, the smart pillow is the future of sleep technology that let user sleep easily and keep track of their sleep data.

1.2 Problem Statement and Motivation

To maintain a healthy body and have a healthy life, human needs enough sleep. Sleep is a part of human's life and it involves in human's daily routine because for adults, they need to sleep at least 7 hours to 9 hours per day (National Sleep Foundation, 2015). Hence, around one-third of our time is used to sleep. Sleeping helps in resting human's brain. But, the quality of sleep varies with everyone. By monitoring the physiological parameters during sleeping, the quality of sleep can be determined. Therefore, the quality of sleep of humans plays an important role in monitoring their physiological parameters.

By the way, American Academy of sleep medicine shows that 30 to 35% of adults have a brief sign of insomnia. 15 to 20% of adults suffered from a short period of insomnia. But it only lasts less than three months. 10% of adults have a serious insomnia disorder. It happens at least three times per week for at least three months. Therefore, insomnia is quite common for adult, smart pillow can easily trace back what is the sleeping quality and help to improve it. But currently in the market now, the smart pillow is quite expensive, some of the people might can't afford it. Hence, a specially designed Low-Cost Smart Pillow is needed to provide the second option to users and let user more understand and monitor his/her sleeping quality and improve it.

1.3 Project Objective

At the end of this final year project, a Low-Cost Smart Pillow will be developed to help improve sleep quality among the users. The objective of this project is to provide a Low-Cost Smart Pillow that able to record the sleeping data of users and upload to IoT platform enable the user to trace the sleeping data. Based on these data, users can know how and what to do to improve their sleeping quality.

The data of Low-Cost Smart Pillow is collected from the head, so the safety is a very important factor in this project. The Low-Cost Smart Pillow must be safe to use to avoid any unfortunate incident from happening such as short circuit.

Sub-objectives:

- Portable – Enable the Low-Cost Smart Pillow to brought to use it.
- User-friendly – Simplify the procedure while using the low-cost smart pillow.

1.4 Project Scope

This final year project aim is to design and create the Low-Cost Smart Pillow in order public can afford it and help the insomnia person to improve their sleeping quality by using a smart pillow. The Low-Cost Smart Pillow consists of some of the sensors that able to detect and record some parameter which is light, temperature and humidity that can be affect sleeping quality. The Low-Cost Smart Pillow will be built using low-cost components to make it more affordable for the public. An IoT platform will be utilized as an online database for Low-Cost Smart Pillow. The IoT platform provides an interface to the user and retrieve out sleeping data that upload from the Low-Cost Smart Pillow and provide some recommendation and sleep quality rating based on several circumstances. This Low-Cost Smart Pillow is built using the sensor to trace the sleeping pattern and collect some of the factors that affecting sleep quality, these data will be collected by Arduino Uno. After that, Arduino Uno will transfer all the sensor value via UART to Raspberry Pi, Raspberry Pi will upload all sensor value to IoT platform to analysis and store purpose.

1.5 Impact, Significance and Contribution

This project develops a Low-Cost Smart Pillow to help analyse and improve their sleeping quality. Besides, this project will help insomniac improve sleep problems as well. This Low-Cost Smart Pillow consists of 2 parts which include hardware and the IoT platform. For hardware implementation part which is the user sleeping pattern and parameter of a factor that can affect sleep quality that will be collected by Arduino Uno, after that, Arduino Uno will send all the sensor parameter via UART to Raspberry, Raspberry Pi will upload all sensor value to IoT platform for further analysis. The software implementation part will enable the Raspberry Pi connect to IoT platform and able to upload all the sensor data to the IoT platform. The IoT will provide a GUI that displays the sleeping quality, and some recommendation for the user to improve their sleeping qualify.

Furthermore, this project can contribute to the insomniac improve sleep problems and step-up their productivity. With this low-cost smart pillow, they can know well how their sleeping quality is and able to enhance based on the recommendation of this mobile WebView application. Not only that, this Low-Cost Smart Pillow can be power on by portable charger or wall plug. That's mean this Low-Cost Smart Pillow is portable can be brought everywhere to use it.

1.6 What Have Been Achieve

The highlights of what have been achieved in this final year project are listed as below:

- A prototype Low-Cost Smart Pillow was built.
- Low-Cost Smart Pillow Sensor Board was designed and built.
- All the sensor node able to collect the data.
- Arduino able to collect sensor data and transfer to Raspberry Pi.
- Raspberry Pi able to communicate and upload sensor data to the IoT platform.
- Able to display sleep data and recommendation on IoT platform.
- Able to remote shutdown the Low-Cost Smart Pillow using IoT platform.
- Enable voice command to control the Low-Cost Smart Pillow

1.7 Report Organization

The details of this final year project are shown in the following chapters. In Chapter 2, some related work reviews are made, and some comparison of related works are done too in this chapter. Besides, the designs of the Low-Cost Smart Pillow, the IoT platform and the procedure of using Low-Cost Smart Pillow are discussed in Chapter 3. Then, Chapter 4 discussed the methodology method of this final year project and the tools used in this final year project. Furthermore, Chapter 5 discuss the implementation and testing of the Low-Cost Smart Pillow to test whether the system is functional or not. Meanwhile, discussion of sleep quality classification, strength or weakness of this system and future enhancement are discussed in this chapter also. Lastly, Chapter 6 discuss the conclusion of this final year project such as the project review.

Chapter 2: Literature Review

There are many researchers work hard on implementing a new Smart Pillow for the future. Some of the researcher's works will be discussed and the advantages and the disadvantages of the systems will be compared as well.

2.1 Sensor Pillow System: Monitoring Respiration and Body Movement in Sleep.

The aim of this research is to present “Sensor Pillow System” to gauge the physiological parameters in sleep without constraint to a human (Harada *et al.*, 2000). Besides, an uncomplicated motion model which gauge the transform of the head pressure distribution together with respiration is presented in this research. The performance of this system is experimentally shown by comparing the counted by a video or image and medical equipment with a number of respirations counted by the Sensor Pillow System.

2.1.1 The Design of the System

This system consists of an array of pressure sensors under the pillow, a one-chip microcomputer to digitize and transmit the pressure data to a desktop computer and the computer to count respirations and turns in sleep.

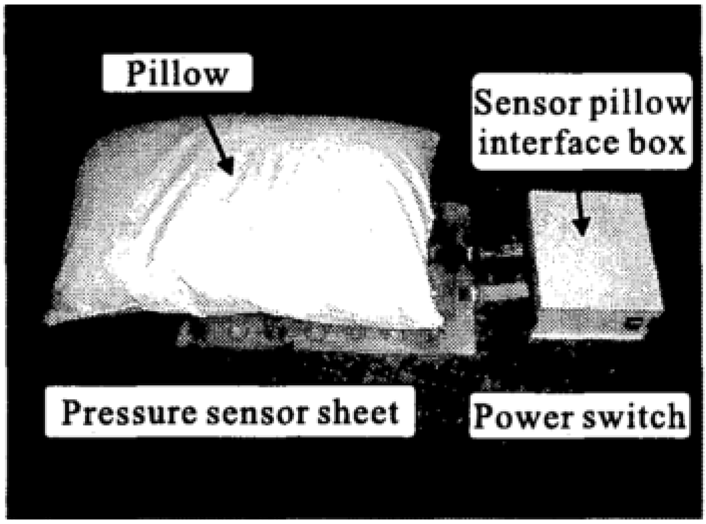

Figure 2.1.1: Sensor Pillow System

Firstly, sensor pillow will measure pressure information caused by the head movement. After that, pressure sensor information will be pass to microcomputer from two multiplexers of sensor pillow interface box to convert to analog information to digital pressure sensor digital. Furthermore, the digital pressure sensor information will be transfer to the body movement tracking and respiration computer via FM transmitter module. Finally, the computer will be based on the measured pressure sensor information analysis and display counts turn in sleep and respiration.

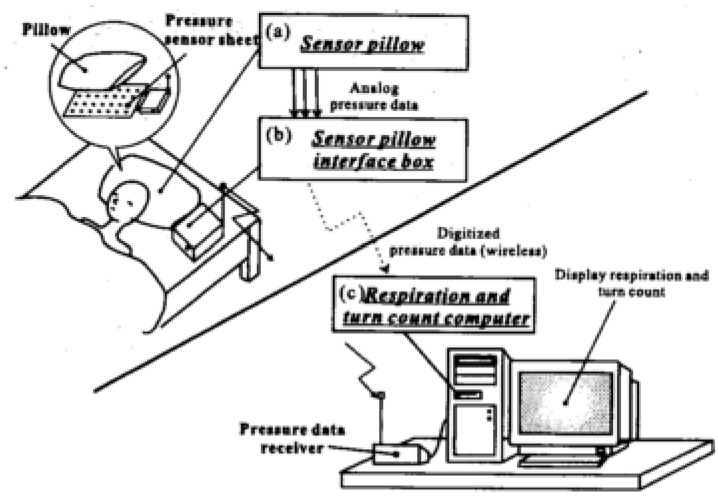

Figure 2.1.2: Overview of Sensor Pillow System

2.1.2 Advantages and Disadvantages

Advantages	Disadvantages
• **Portability** This system is portable and allows a user use it anywhere.	• **Privacy Issue** there is an unrestrained respiration detecting system that observing a body movement and user respiration in sleep by using the camera. So, this system is not suitable for users who are worrying about an incursion of privacy.
• **Small and simple** This system is so small and simple that everyone without any special knowledge can use this system every day.	• **Hygienic Problem** Since exchanging beds is a great task for ordinary people, introducing these systems to ordinary homes is very difficult.

Table 2.1.1: The advantages and disadvantages of the Sensor Pillow System

2.1.3 Comparison with the proposed solution

The mentioned system above may incursion of user privacy because this system was using the camera to monitoring body movement and user respiration. Unlike the proposed solution, only force sensitivity resistor will be used for tracking user body movement. For those who concern their privacy, the proposed solution does not have to exist this kind of issue.

2.2 Real-time Auto Adjustable Smart Pillow System for Sleep Apnea Detection and Treatment.

The aim of this research is designed and developed a real-time and auto adjustable smart pillow system. This system is capable to notice sleep apnea in real time using a pulse oximeter to adjusting the height and shape of the pillow in order mitigate sleep apnea (Zhang *et al.*, 2013). Besides, this research using a non-incursive device, low-cost and portable to enable both sleep apnea detection and cure in a home environment.

2.2.1 The Design of the System

This system is based on two consideration which is blood oxygen concentration is a great symbol to identify sleep apnea incident, by using a pulse oximeter to observing blood oxygen concentration, the sleep apnea incident can be identified in real time. To confirm that the device can be used at ease and use in the home environment, arterial blood oxygen sensor also called pulse oximeter will be used to detect the sleep apnea incident. Once the sleep apnea incident is identified, the pillow will automatically adjust its shape and height and it controlled by the mobile phone-based central controller. A real-time feedback pillow adjustment algorithm is designed by them to decide how and when to adjust the pillow and appraise the effectiveness of the adjustment.

Figure 2.2.1 shows the overall system architecture of smart pillow system. First, the pulse oximeter implements SpO2 detecting continuously and transfer the warning signals to the apnea detection module and analysis module in the mobile phone.

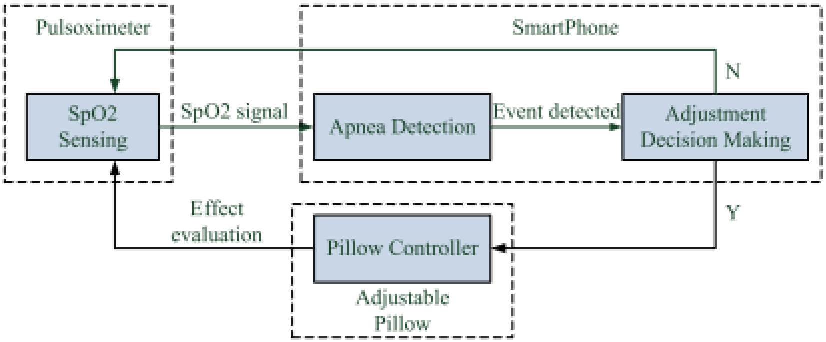

Figure 2.2.1: System architecture of Real-Time Auto Adjustable Smart Pillow System for Sleep Apnea Detection and Treatment.

The apnea event will be identified by apnea detection module and transfer the result to the adjustment decision-making module, which actually carries out on the mobile phone. The structure of Real Time Auto Adjustable Smart Pillow System for Sleep Apnea Detection and Treatment is shown in Figure 2.2.2, there actually contains five bladders inside the smart pillow.

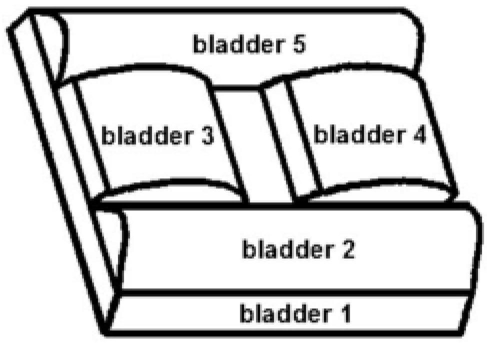

Figure 2.2.2: Overview of Real Time Auto Adjustable Smart Pillow System for Sleep Apnea Detection and Treatment Structure

2.2.2 Advantages and Disadvantages

Advantages	Disadvantages
• **Real-time and auto adjustable pillow** The shape and height of the pillow can automatically adjust to mitigate the sleep apnea incident.	-
• **Convenient** It can let patients use the device in a home environment because it is portable.	-

Table 2.2.1: The advantages and disadvantages of the Real Time Auto Adjustable Smart Pillow System for Sleep Apnea Detection and Treatment

2.2.3 Comparison with the proposed solution

The mentioned system above is using a pulse oximeter to detect whether sleep apnea incident is it happens, in case it happened the shape and height of the pillow will be automatically adjusted to mitigate the sleep apnea incident. Unlike the proposed solution, the proposed solution is detecting user sleeping pattern and another factor that might affect user sleep quality. From the information that collects by the sensor node, this information will be analysed and transform to sleeping chart and some of the recommendation that can be let user improve their sleeping quality using smart pillow application on their smartphone.

2.3 Smart Pillow— Intelligent system to comfort newborn infants using vibration and monitoring movement of the infants via wireless.

The aim of this research is deliver a new design and concept for comforting newborn baby, which aims at comforting preterm neonates by imitate some of the behavior of the baby‘s mother or father and making the behavior available to the baby when the parents not around preterm neonates (Archana devi.S.M, Chandra sekar.G and Janarthanan M, 2016).

2.3.1 The Design of System

This smart pillow is a device that would make an active improvement even when parents are not around to their baby by providing comfort both to the child and the parents. Therefore, they designed the smart pillow to play heartbeat vibrations and measure PPG signals to comfort the newborn baby.

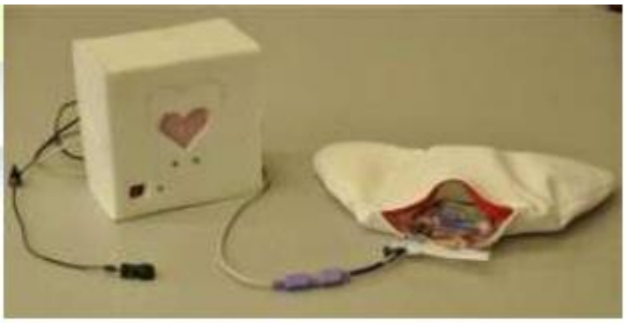

Figure 2.3.1: The prototype of the smart pillow

The Mimo recorder that let parents of the newborn baby make a recording of their heartbeat and it is a white cubical box. A heartbeat photoplethysmograph (PPG) is attached to the side of the box. The front of the box contained a number of LEDs that indicated the status of the recording process and there have a button to start up the recording process. An overview of the circuitry inside the Mimo recorder can be found in Figure 2.3.2.

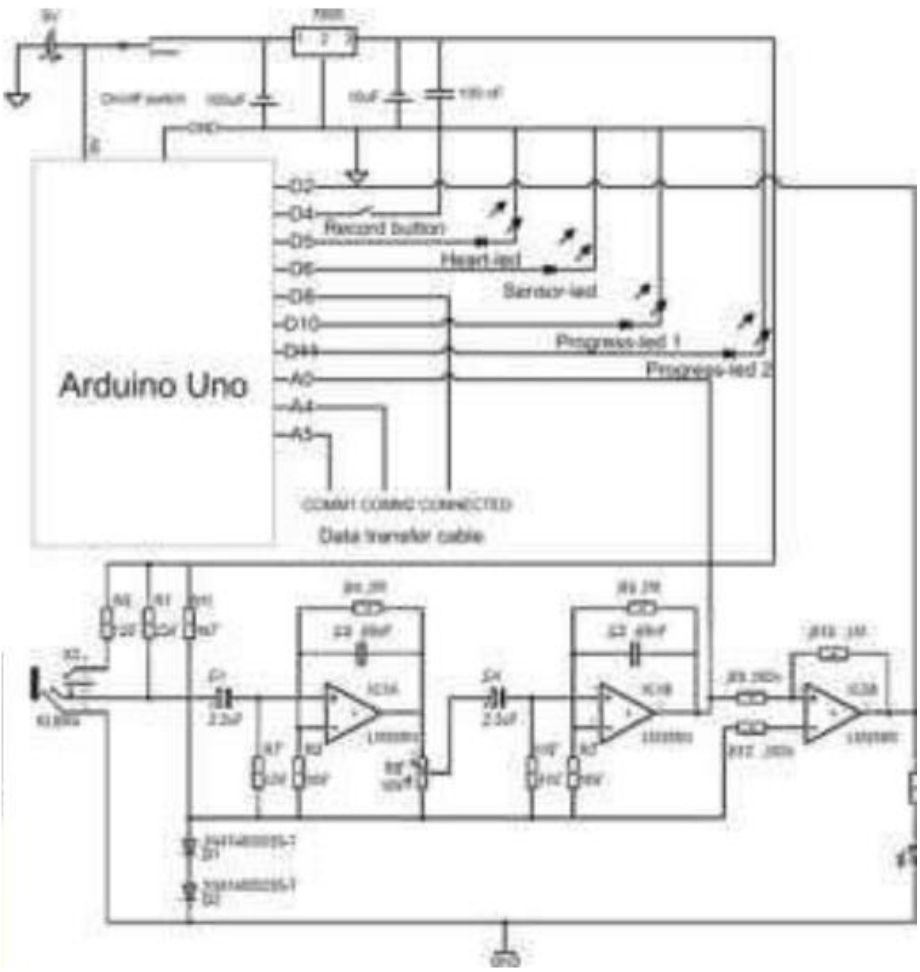

Figure 2.3.2: An overview of the circuitry of Mimo recorder

The core of the Mimo recorder is an Arduino Uno microcontroller, and it's supplied by a 9-V battery. The Arduino Uno has performed nearly the complete recording stages, from sensing from parent’s heart rate and transfer to transmission of the heartbeat to the pillow. To ensure the extreme portability to parents for their selection of a recording environment, it was purposely chosen to use a battery rather than a fixed power supply. The method of using Mimo recorder is using heartbeats of the mothers of a newborn baby were recorded into the Mimo recorder. The particular signal was uploaded to the Mimo pillow. After that, switch in the Mimo pillow it will be felt rhythmic vibrations on the surface of the Mimo pillow. After baby diaper change before their feeding parent can use Mimo pillow placed on the chest of the babe.

2.3.2 Advantages and Disadvantages

Advantages	Disadvantages
• **Easy to set up and easy use** Parents could record their physiological data on their own without the guidance of a nurse.	• **Only prototype available** The current design is only a prototype for tests and demonstration purposes.
• **Washable and clinically safe** This device is meet hospital standards.	

Table 2.3.1: The advantages and disadvantages of the Smart Pillow— Intelligent system to comfort newborn infants using vibration and monitoring movement of the infants via wireless

2.3.3 Comparison with the proposed solution

The mentioned system above is playing heartbeat vibrations and measure PPG signals to comfort the newborn baby when their parents are not around. Unlike the proposed solution, the proposed solution is detecting user sleeping pattern and another factor that might affect user sleep quality. From the information that collects by the sensor node, this information will be analysed and transform to sleeping chart and some of the recommendation that can be let user improve their sleeping quality using smart pillow application on their smartphone.

2.4 Sensor Pillow and Bed Sheet System: Unconstrained Monitoring of Respiration Rate and Posture Movements During Sleep

The aim of this research is developed a low-cost sleep monitoring system for the patient based on polysomnography which will be convenient for patient deliver their need with healthcare personals and/or relatives (Lokavee *et al.*, 2012). Besides, it offers a simple motion model that clarifies the body pressure distribution and change of head.

2.4.1 The Design of System

This system is designed and develop an alternate of ballistocardiographic (BCG) system as a sleep information observing equipped with force sensitive resistors (FSR) based on polymer thick film (PTF) equipment. Besides, they also established a sleep observing system contain a force sensitive resistors (FSR) and a normal pillow, a ZigBee network and computer software that build for real-time pillow and bed movement detection. The wireless network that used to transfer information to a computer was using low-cost ZigBee technology. ZigBee is a technology based on the IEEE 802.15.4 standard that uses for communication in order to provide ultra-low power consumption. Hence, the ZigBee technology is very suitable for implementation of this project where a huge number of bed sheet and pillows can be connected together. The schematic of the bed sheet and sensor pillow system for observing body movement and respiration rate throughout sleep is shown in Figure 2.4.1.

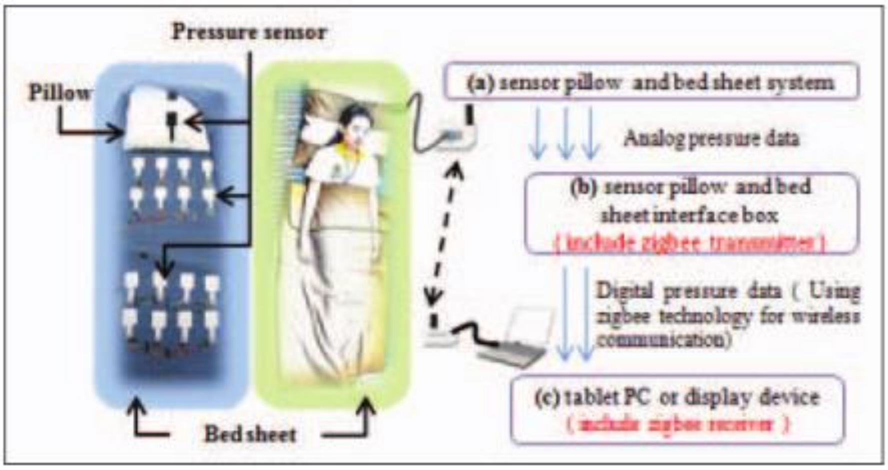

Figure 2.4.1: Schematic of sensor pillow and bed sheet system

The system contains 3 primary peripheral which is force sensitive resistors sensor that embedded on the bed sheet and pillow, wireless network devices based on low-cost ZigBee technology for getting and transmitting information of the force sensitive resistors to computer or other display device via wirelessly and a customize software to evaluate and classify respiration rate and body movement. Figure 2.4.2 shows that the schematic of the transmitter module and receiver module.

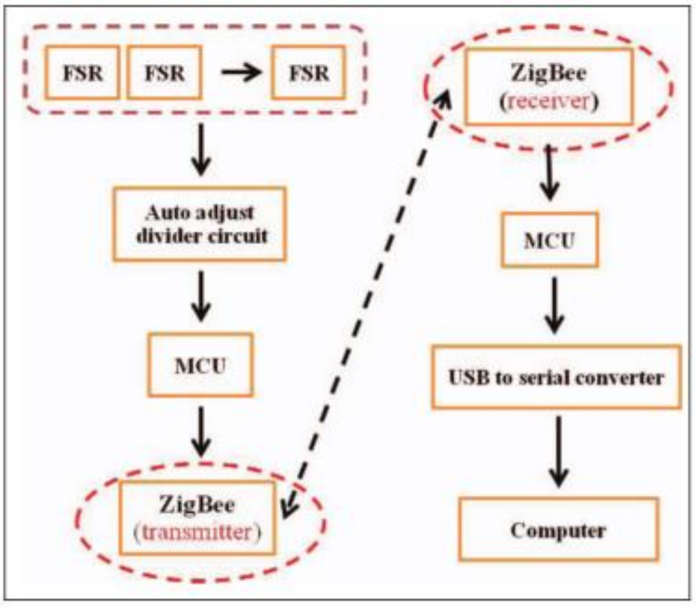

Figure 2.4.2: Schematic of transmitter module and receiver module

A microcontroller from Microchip (PIC18F45J10) was chosen as the main control unit. First, it obtains sensor signals from the force sensitive resistors sensors and transfers the information to the ZigBee transmitter module using the Universal Asynchronous Receiver Transmitter (UART) protocol. The voltage buffer receives information from the voltage divider circuit that is precisely linked to the force sensitive resistors sensors. After that, the microcontroller reads analog voltage from the voltage buffer and translates these analog signals to digital data and generate a digital data packet to transfer wirelessly to the ZigBee receiver. The sensor pillow and bed sheet system is not only suited of observing the body movements but also determining the physiological parameters like twitch movements action, heart and respiration status and activity.

2.4.2 Advantages and Disadvantages

Advantages	**Disadvantages**
• **Inexpensive** Only low-cost hardware included in this design.	-
• **Scalability** allows multiple pillows, bed sheet, and other devices to be added into the networks with ZigBee wireless network devices	-

Table 2.4.1: The advantages and disadvantages of the Sensor Pillow and Bed Sheet System: Unconstrained Monitoring of Respiration Rate and Posture Movements During Sleep.

2.4.3 Comparison with the proposed solution

The mentioned system above is using few force sensitivity resistor sensors to cover pillow and bed sheet in order to track user sleeping posture. This system used ZigBee which is low-cost wireless technology, this enable system to add in multiple pillows and bed sheet into the system. This system only focuses body movement of the user but no other factor that might affect user sleeping quality. Unlike the proposed solution, the proposed solution is detecting user sleeping pattern and another factor that might affect user sleep quality. From the information that collects by the sensor node, this information will be analysed and transform to sleeping chart and some of the recommendation that can be let user improve their sleeping quality while using smart pillow application on their smartphone.

CHAPTER 3: System Design

To design and develop a Low-Cost Smart Pillow, a sensor collector and a software are required. Hence, this prototype will be built using some low-cost components and a development board.

3.1 Full System Diagram

The full system diagram of this final year project is shown in Figure 3.1 below.

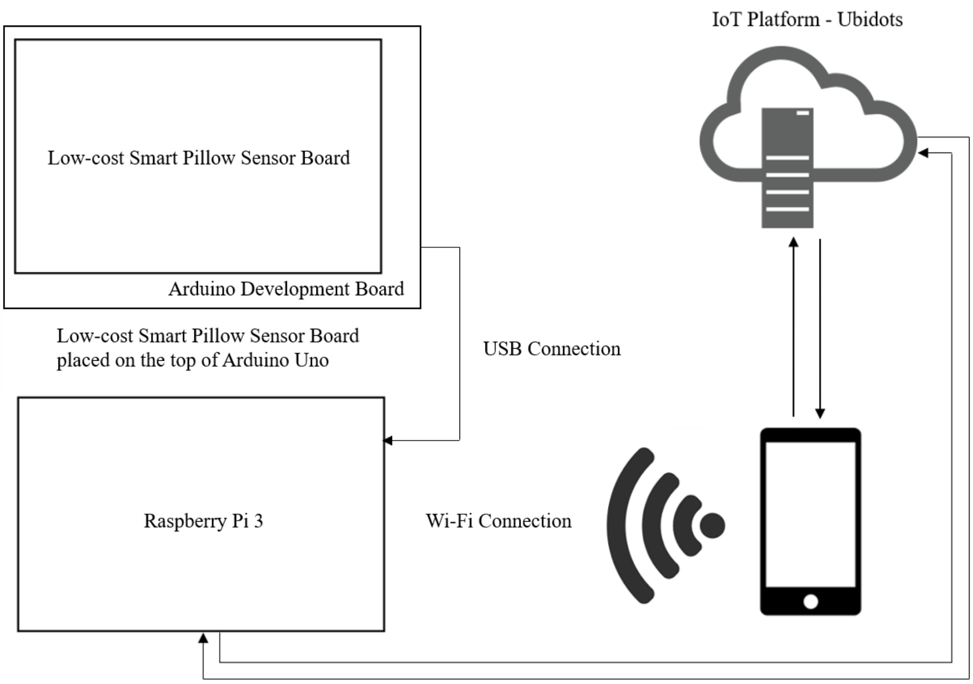

Figure 3.1.1: Full System Diagram

In this final year project, the Arduino Uno is used as the microcontroller to read data from sensor nodes. The Low-Cost Smart Pillow Sensor Board is built by using the concept of Arduino Shield. The sensor component has humidity & temperature sensor, light intensity sensor, 3 of force sensitive resistor and 3 of 10k Ω resistors. The purpose of design and create Low-Cost Smart Pillow Sensor Board can keep the prototype free of jumper wires that use for connection between Arduino Uno and sensor nodes. The Low-Cost Smart Pillow Sensor Board is stacked on the Arduino Uno board for data collection. After that, Arduino Uno will send all the sensor parameter to Raspberry Pi 3 via USB connection but via UART communication. Then, Raspberry Pi 3 will upload the sensor parameter to Ubidots for data storing and sleep quality analysis. Raspberry Pi 3 also retrieve the information from Ubidots that allow Raspberry Pi 3 shutdown or start the python script which is developed for data collecting from Arduino Uno and upload to Ubidots. Meanwhile, A smartphone is used for the user to trace the history of sensor data and review the recommendation of last night. Besides that, the smartphone required to generate a Wi-Fi connection to give Raspberry Pi 3 internet connectivity connection with Ubidots.

3.2 Flow Chart of Full System

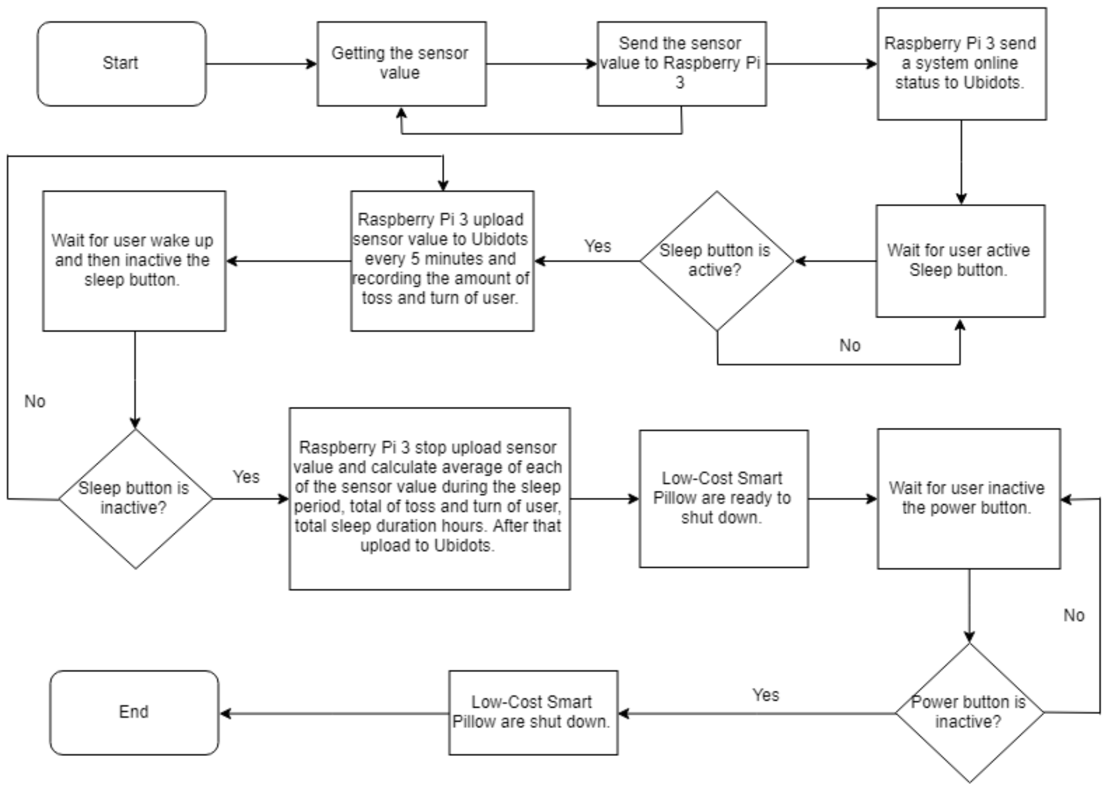

Figure 3.2.1: Flowchart of Full System

3.3 Hardware Implementation

The Low-Cost Smart Pillow consists of a Low-Cost Smart Pillow Sensor Board, Arduino Uno and Raspberry Pi 3. The force sensitive resistor is placed at the top of the pillow for tracking the amount of toss and turn during sleep process. During this hardware implementation, Low-Cost Smart Pillow Sensor Board design and development was carried out and in the end was successful. Figure 3.3.1 below shows the development board and sensor board of Low-cost Smart Pillow in hardware implementation part.

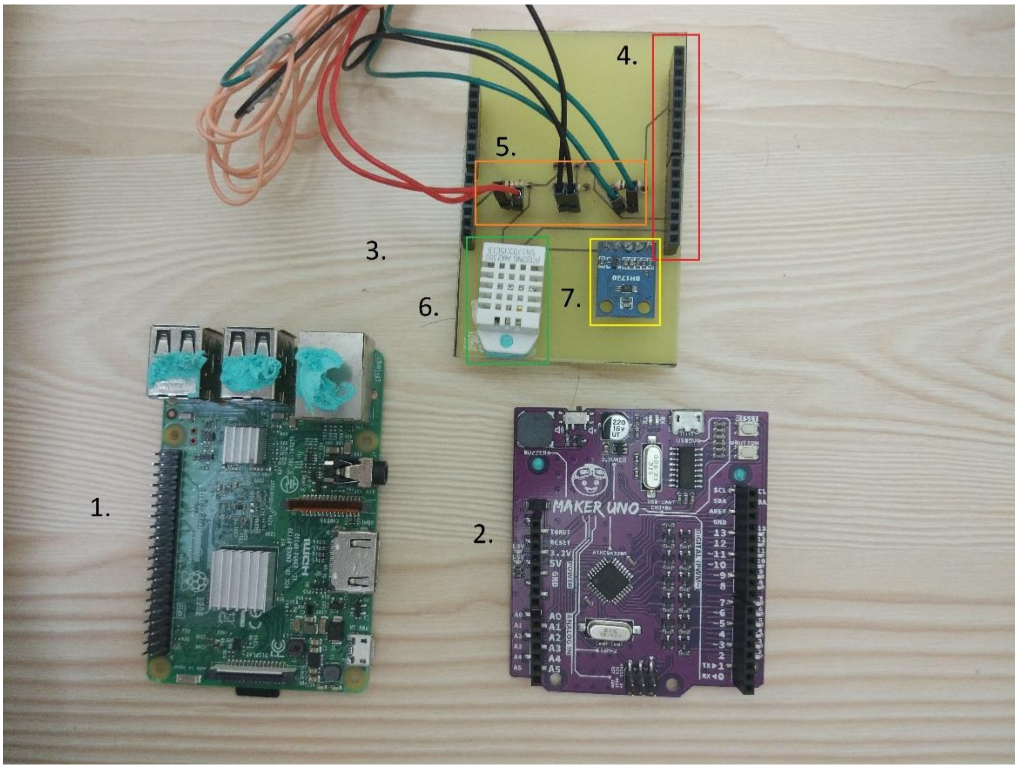

Figure 3.3.1: The development board and sensor board of Low-cost Smart Pillow

1. Raspberry Pi 3
2. Arduino Uno
3. Low-cost Smart Pillow Sensor Board (PCB)
4. Arduino Stackable Female Header
5. Force Sensitive Resistor and 10K ohm resistor
6. DHT22 Digital Temperature & Humidity Sensor Module
7. BH1750 Chip Light Intensity Light Module

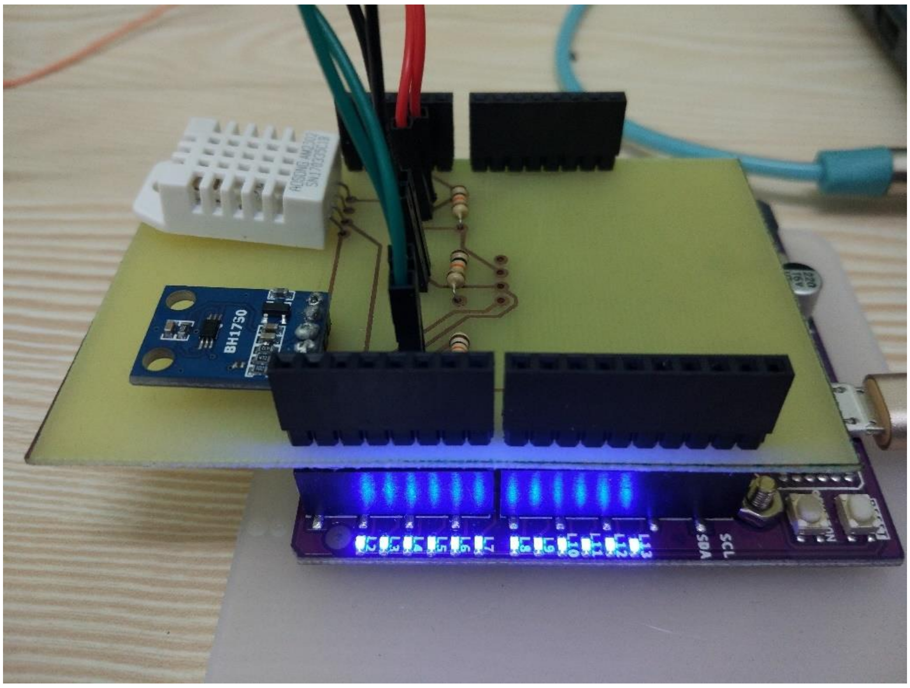

Figure 3.3.2: The Low-Cost Smart Pillow Sensor Board stacked on the Arduino Uno board

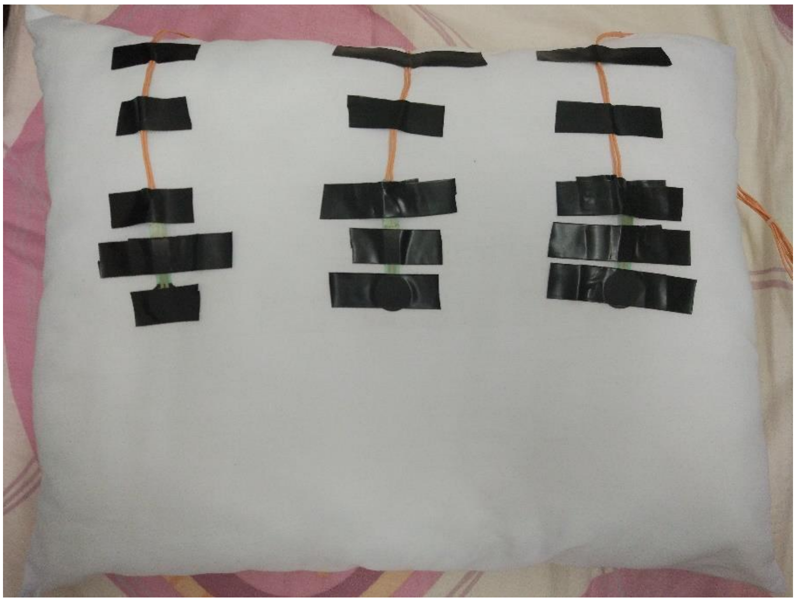

Figure 3.3.3: The Force Sensitivity Resistor is placed on top of the pillow

The Low-Cost Smart Pillow can be power on by using 5V USB Voltage, which means this Low-Cost Smart Pillow can be power by notebook USB port, portable charger or wall plug. Besides, the Low-Cost Smart Pillow can access the internet wirelessly via Wi-Fi connection with the mobile device.

The job of Arduino Uno is to collect all the sensor parameter and send to Raspberry Pi 3 to upload all the sensor parameter to the IoT platform for online storing and sleep quality analysis. Figure 3.3.4 shows the example of sensor parameter that collected by Arduino Uno. First 3 zero is shown the value of Force Sensitivity Resistor, the fourth value is Humidity data, the fifth value is temperature data, following the last one is light intensity data.

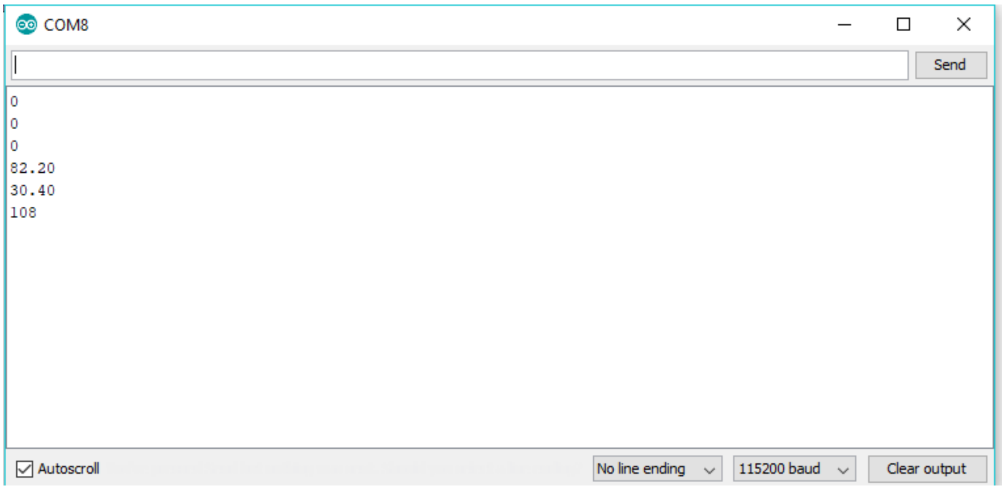

Figure 3.3.4: The sensor parameter printed on the serial monitor

3.4 Software Implementation

For Raspberry Pi 3 part, total has 2 python script was developed to Low-cost Smart Pillow. The first script is named as smart_pillow.py, this is a startup script when the Raspberry Pi 3 is booting.

This script is connected Raspberry Pi 3 to IoT platform and send an online indicator to IoT platform so the user can be informed the Raspberry Pi 3 is connected with IoT platform, after that this script will start getting the data from IoT platform whether have to start the sleeping process program. If the user clicks a sleeping active button on IoT platform, the Raspberry Pi 3 will get the signal and start the sleeping process program. After Raspberry Pi 3 start the sleeping process, Raspberry Pi 3 will turn off the power and MMC LEDs which located on the mainboard of Raspberry Pi 3, it action actually can be acknowledgement user that the sleeping process program is started. Therefore, Raspberry Pi 3 will get all the sensor parameter that from Arduino Uno, after that, it will upload all sensor parameter like temperature, humidity, light intensity to the IoT platform every 5 minutes. Meanwhile, the script is getting the value from Force Sensitivity Resistor to determine the amount of toss and turn in the user sleep process. Sleeping process program will stop once the user clicks sleep active button on IoT platform, the Raspberry Pi 3 will calculate the average of temperature, average of humidity, average of light intensity, amount of toss and turn and total sleep duration from the user sleep process. After all the data are done upload to IoT platform. This script will be called to run the second python script which is called power.py.

The power.py python script is handling for remote shutdown the Raspberry Pi 3 after user uses it. Raspberry Pi 3 is like the personal computer, it can't be hotplug to shut down to avoid data corruption. Therefore, when the power.py python script us running, the power LED will be blinking to acknowledgement the Raspberry Pi 3 is ready to shut down. After that, the user can click the power button on the IoT platform to remotely shut down the Raspberry Pi 3.

For IoT platform part, the IoT platform we chose in this final year project is Ubidots. The Figure 3.4.1 below shows the dashboard of Ubidots. Besides that, this final year project is using Ubidots App too. The Figure 3.4.2 below shows the Ubidots App.

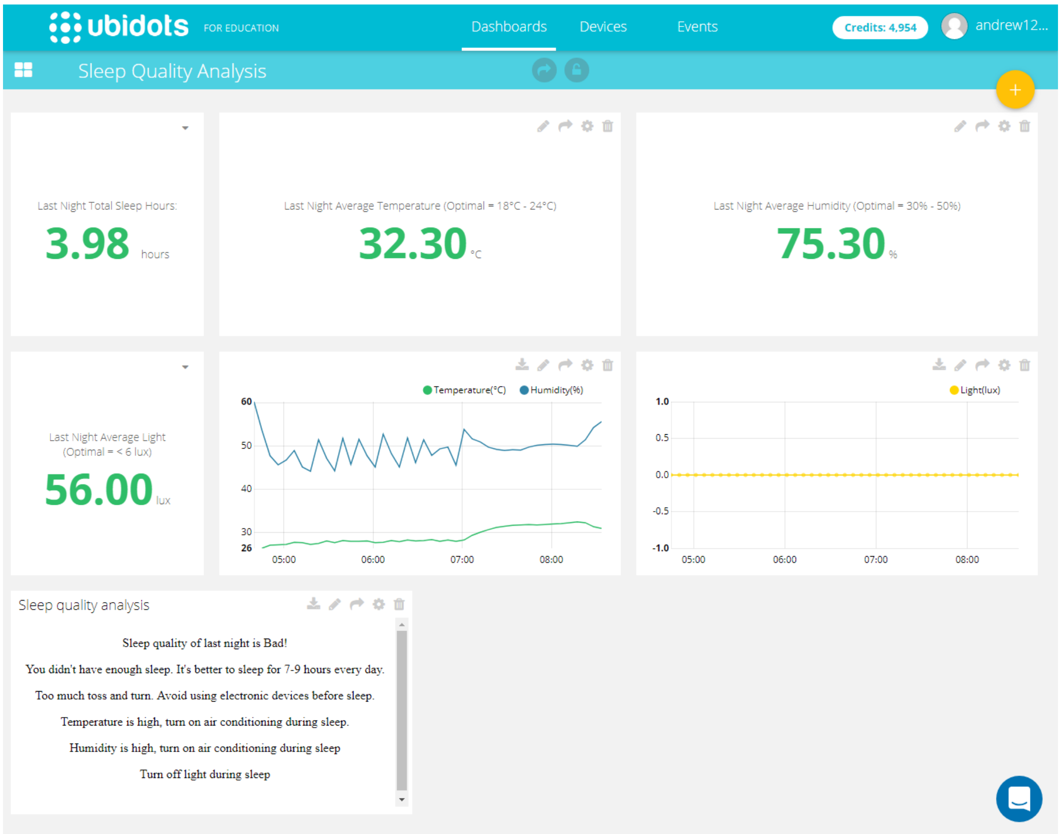

Figure 3.4.1: Dashboard of Ubidots

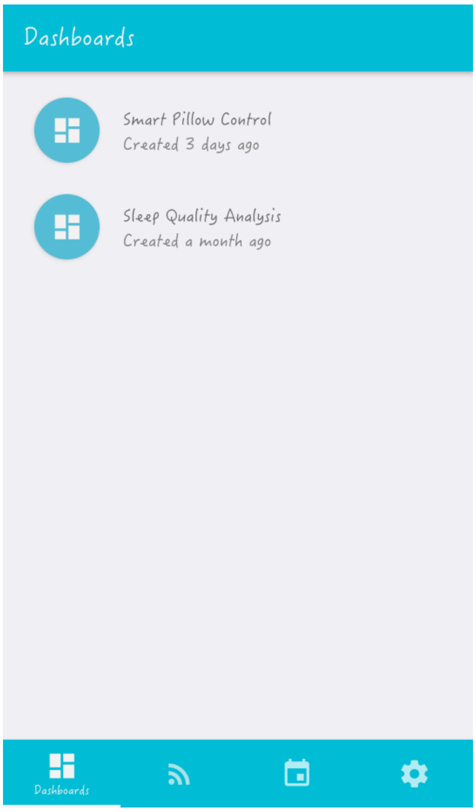

Figure 3.4.2: Ubidots App

In Ubidots development, two of the dashboards are categorized for the user. For example, the user wants to start recording their sleep data, they will go for Smart Pillow Control dashboards, if they want to view their history sleeping data and sleep quality analysis, then Sleep Quality Analysis dashboard is their choice.

In the dashboard of Smart Pillow Control, there have one indicator and two buttons for respective function. The first one indicator is for let user know whether the Low-Cost Smart Pillow is connected to the Ubidots and ready to use. The first button is a button that controls the sleeping process program in Low-Cost Smart Pillow. Once the user wakeup, this button is requiring to click to stop the sleeping process program and generate some data upload to Ubidots. Once the data is uploaded to Ubidots, the second button which is power button will display as active state, the user can click it turn as inactive state for remotely turn off the Low-Cost Smart Pillow. The Figure 3.4.3 is shows below the screenshot of Smart Pillow Control dashboard of Ubidots.

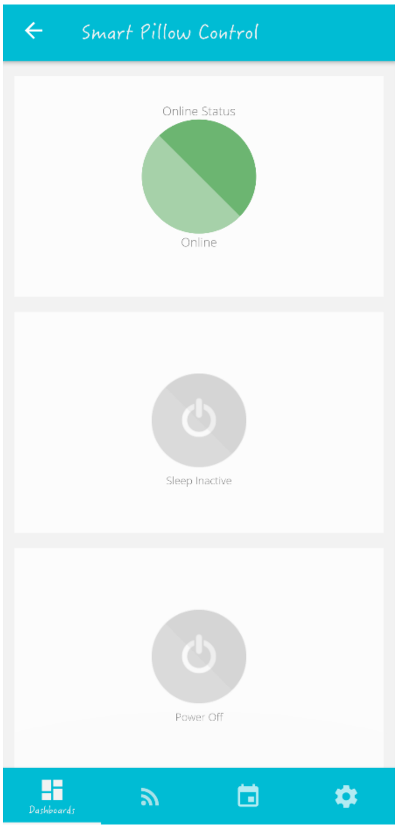

Figure 3.4.3: Smart Pillow Control dashboard of Ubidots

In the dashboard of Sleep Quality Analysis, there are 7 data represent it. The first one data is showing the total sleep duration of the user, second data is the average temperature during the user sleep period, third is the average humidity during the user sleep period, fourth is the average light intensity during the user sleep period. The fifth and the sixth one is the history graph which represented temperature, humidity and light intensity for all night long. Finally, the last one is the sleep quality analysis. In this sleep quality analysis, JavaScript language is required to getting the result from Ubidots and analysis it to give some appropriate recommendation based on sensor data. The Figure 3.4.4 is the screenshot of Sleep Quality Analysis dashboard of Ubidots

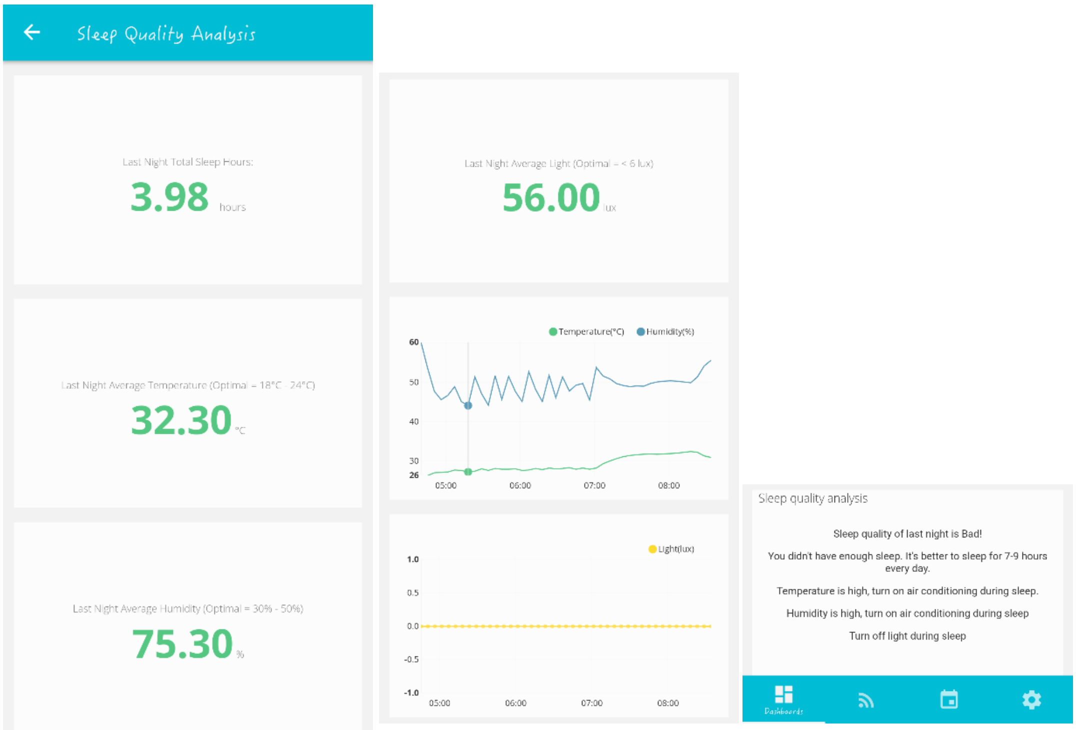

Figure 3.4.4: Sleep Quality Analysis dashboard of Ubidots

Besides that, the Low-Cost smart pillow can be controlled using google assistant. The user can just launch their google assistant and say to it "I'm going to sleep", the Low-Cost Smart Pillow will proceed to the sleeping process mode. When the user wakes up can just use voice command "I'm wake up", the Low-Cost Smart Pillow will stop the sleeping process mode and generate the data to the Ubidots. Last but not least, the Low-Cost Smart Pillow can be remotely shut down by using voice command "Shutdown the smart pillow" to google assistant. Figure 3.4.4 is the screenshot of the voice command to launch the sleeping process mode. Figure 3.4.5 is the screenshot of the voice command to stop the sleeping process mode. Figure 3.4.6 is the screenshot of the voice command to shut down the Low-Cost smart pillow.

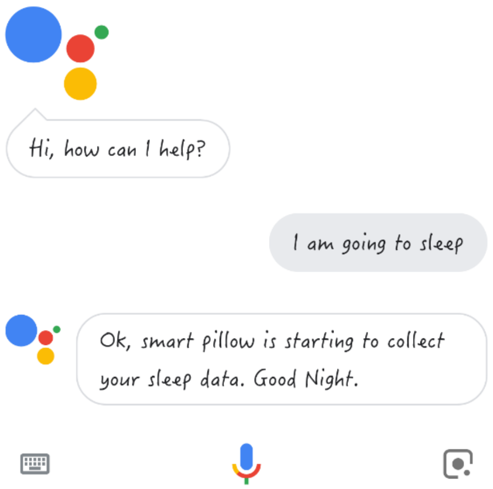

Figure 3.4.5: Voice command to launch the sleeping process mode

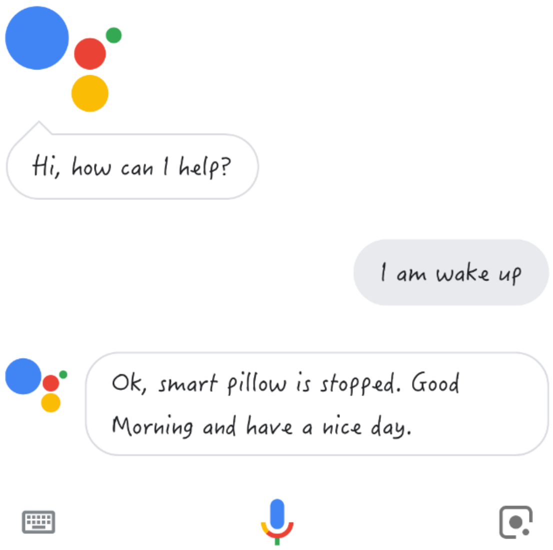

Figure 3.4.6: Voice command to stop the sleeping process mode

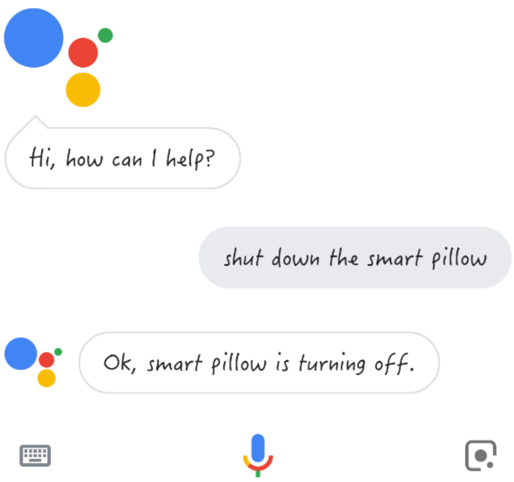

Figure 3.4.7: Voice command to shut down the Low-Cost smart pillow

3.5 Procedure for using Low-Cost Smart Pillow

To starting to use Low-Cost Smart Pillow, a stable internet connection is required to ensure the connectivity between Ubidots. In this final year project, a stable internet connection is provided by the smartphone, before turning on Low-Cost Smart Pillow, we need turn on the wireless hotspot in smartphone first. After it done, plug in the power source for the USB attach with the Low-Cost Smart Pillow. After Low-Cost Smart Pillow is successful turn on and connected to Ubidots. In the dashboard of Smart Pillow Control, we can see that the online status indicator turned green color. The figure 3.5.1 show the online status indicator turned green color.

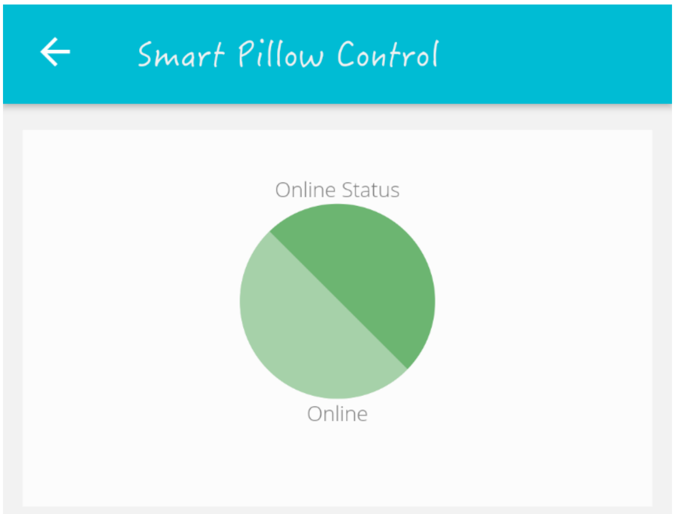

Figure 3.5.1: Online status indicator turned green color

After that, the user can click the sleep active button which located in the dashboard of Smart Pillow Control to start the sleeping process mode. The figure 3.5.2 shows the sleep active button in the dashboard of Smart Pillow Control.

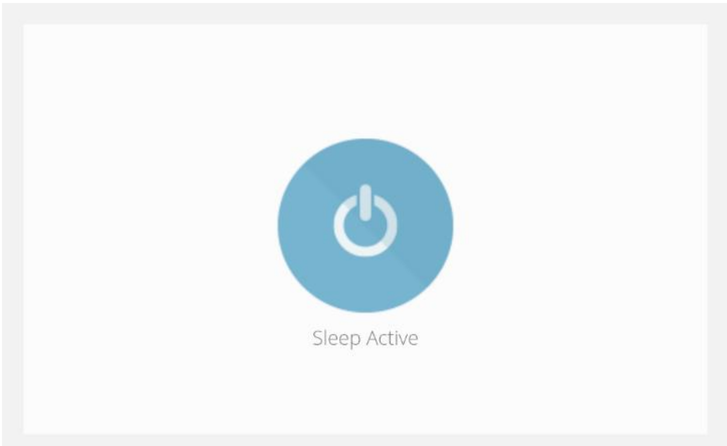

Figure 3.5.2: Sleep active button in dashboard of Smart Pillow Control

Once the sleep active button is clicked, the Low-Cost Smart Pillow turns off the power and MMC LEDs which is green and red color to acknowledgement to the user the Low-Cost Smart Pillow is ready for collect the sleeping data. The Low-Cost Smart Pillow will collect the amount of user toss and turn during this sleep period and all the sensor data will upload it to Ubidots every 5 minutes for a graph output. When the user is wake up, he/she required to click again sleep active button and the button will change to sleep inactive. Therefore, the Low-Cost Smart Pillow will stop collecting the sensor data and do some calculation like average for the sensor data, sleep duration. Once the Low-Cost Smart Pillow is done calculating and uploaded to Ubidots. In dashboard of Sleep Quality Analysis, it will show the last night sleep hours, average temperature for last night, average humidity for last night, average light intensity for last night, history graph for temperature humidity and light intensity for last night. Based on this several parameters, the Low-Cost Smart Pillow is able to classify the sleep quality of the user and giving some recommendation to improve the sleep quality of user. Meanwhile, once the sleep active button is clicked again, the power button in the dashboard of Smart Pillow Control will become active and the Low-Cost Smart Pillow will blink the power LED which is red color to acknowledgement user the Low-Cost Smart Pillow is ready for turn off. User can click the power button to turn off the Low-Cost Smart Pillow. The Figure 3.5.3 is showing the power button in the dashboard of Smart Pillow Control. The Figure 3.5.4 is showing the location of power LED and MMC led of Low-Cost Smart Pillow.

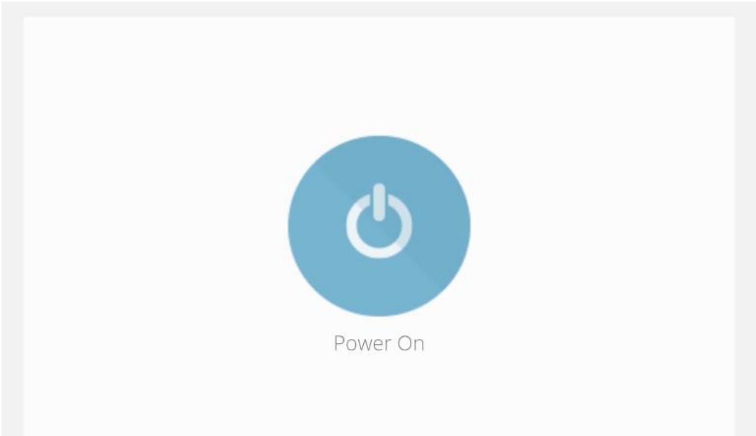

Figure 3.5.3: Power button in dashboard of Smart Pillow Control

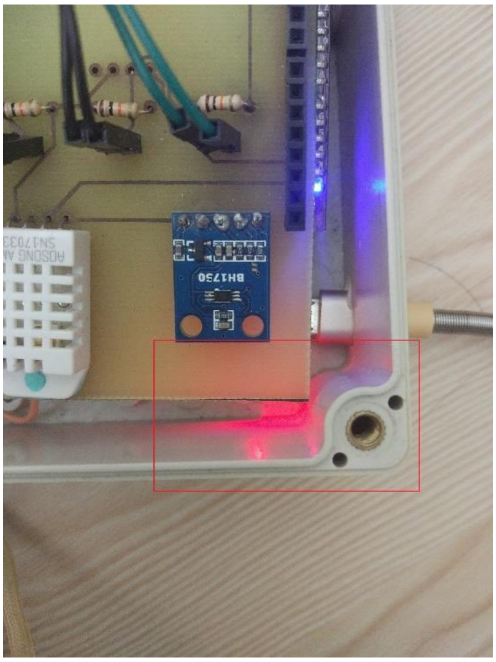

Figure 3.5.4: Location of power LED and MMC led of Low-Cost Smart Pillow

CHAPTER 4: Methodology and Tools

4.1 Design Methodology

The design methodology is referring to the way for a unique situation or a development of a system. The purpose to design methodology explores the greatest solution for respectively design situation. An excellent design methodology can assist develop a good system. Thus, the System Development Life Cycle (SDLC) is investigated. The System Development Life Cycle (SDLC) is a development that develops a system with the lowest cost and greatest quality in the shortest period. System Development Life Cycle (SDLC) come with a detailed plan for how to design, modify, maintain, and change a system. System Development Life Cycle (SDLC) contains several different stages, together with requirement analysis, design, implementation, testing, and evolution. Several famous System Development Life Cycle (SDLC) models have Waterfall Model, Spiral Model, and Agile Model and Prototype Model. The Figure 4.1.1 below shows the stages of the System Development Life Cycle (SDLC).

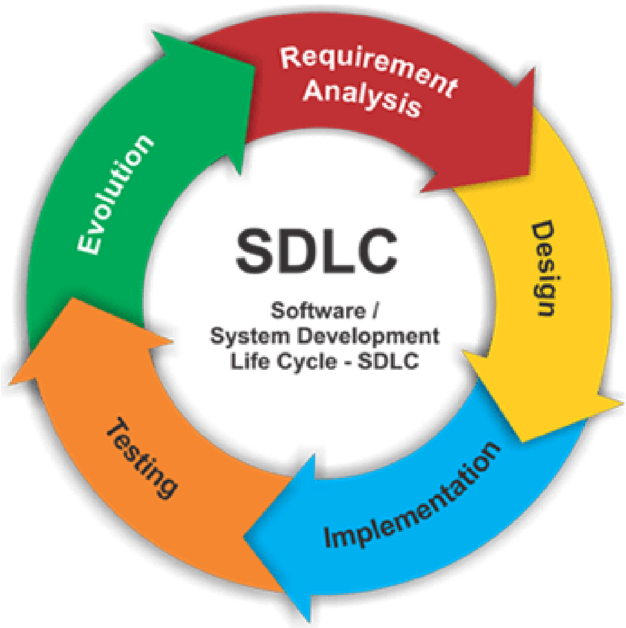

Figure 4.1.1: The stages of the System Development Life Cycle (SDLC)

In this final year project, the Prototype Model is chosen to develop a good system. The Prototype Model shows that develop a prototype with the meet general functionality of the system and it helps the developer understand the customer requirements at the very early stage of the development. Besides that, with developed prototype, it can reduce the times and cost of development. Prototype improves the quality of specifications and requirements provided to the client. Any changes future in development cost exponentially more to implement. The final goal of Prototype Model is to provide a system with general functionality. The Figure 4.1.2 below shows the general steps of Prototype Model.

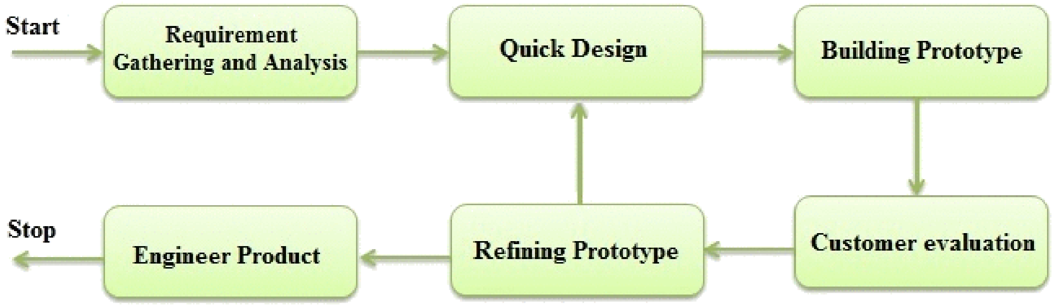

Figure 4.1.2: The general steps of Prototype Model

There are 6 general steps for Prototype Model as shown in Figure 4.1.2 above.

It includes:

1. Requirement Gathering and Analysis – In this phase, the developer is required done the basic requirement. After that, the requirements will be analyzed. The product requirement tools documents will be produced by developer.
2. Quick Design – The developer will start to develop the initial prototype of the system based on client requirements. The initial prototype may not exactly work in the same manner as the actual system developed. But it gives the client a similar look and feels as the final system development.
3. Building Prototype – A prototype is developed from the initial prototype. In this stage, this prototype gives a look and feel similar as the final system has to be develop.
4. Customer evaluation – After building the prototype of the system, the client checks the working functionality of the developed prototype and gives a feedback and reviews to the developer.
5. Refining Prototype – The developer will revise and enhance the prototype based on client feedback and reviews. If the client satisfied with the final prototype, the developer can proceed to the next stage.

6. Engineer Product – The actual system will be developed based on the final prototype.

4.2 System Requirement

4.2.1 Hardware Components

- DHT22 Digital Temperature & Humidity Sensor Module

  Figure 4.2.1 is a picture of DHT22 Digital Temperature & Humidity Sensor Module. DHT22 Digital Temperature & Humidity Sensor Module is come with AM2302 output calibrated digital signal which means we don't need extra Analog to Digital Converter (ADC) to process the data.

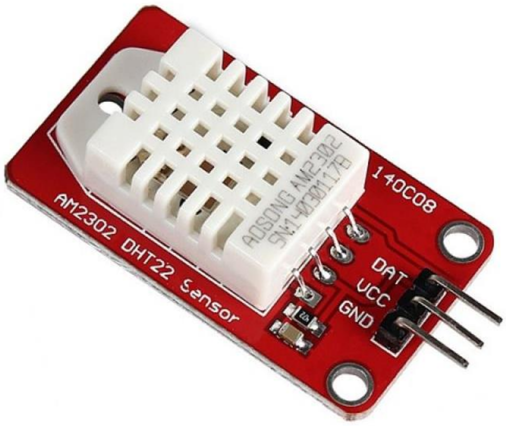

Figure 4.2.1: DHT22 Digital Temperature & Humidity Sensor Module

This module will collect the temperature and humidity data and then convert to digital data after that transfer to microcontroller unit which is Arduino Uno. DHT22 Digital Temperature & Humidity Sensor Module used to collect the temperature and humidity data during the period of while user sleeping.

- BH1750 Chip Light Intensity Light Module

Figure 4.2.2 is a picture of BH1750 Chip Light Intensity Light Module. GY-302 BH1750 Chip Light Intensity Light Module is based on BH1750FVI ROHM Chip. This module built-in 16 bits analog to digital converter (ADC) and its able direct digital output, with this feature it can bypass the complicated calculation and omit calibration.

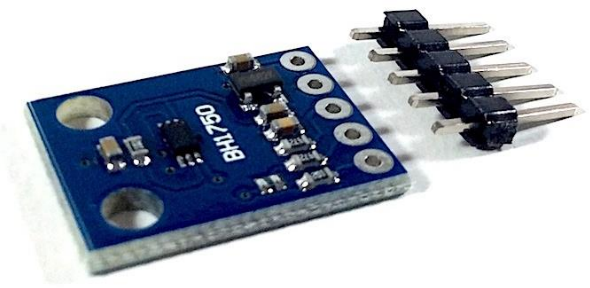

Figure 4.2.2: BH1750 Chip Light Intensity Light Module

It able to detect the light intensity from surrounding and output the LUX (luminous flux per unit area) value to Arduino Duo. GY-302 BH1750 Chip Light Intensity Light Module is used to collect the light intensity of surrounding the Low-Cost Smart Pillow.

- Force Sensitive Resistor

  Figure 4.2.3 is the picture of Force Sensitive Resistor. This Force Sensitive Resistor will vary its resistance depending on how much pressure is being applied to the sensing area. The harder the force, the lower the resistance. Therefore, the force pressure can be measured.

Figure 4.2.3: Force Sensitive Resistor

Force Sensitive Resistor is used to collect body movement while user using the Low-Cost Smart Pillow, this data can help us trace the amount of toss and turn of entire sleep process, from the data we collect from force sensitive resistor we able to know the user is it suffers toss and turn issue during sleep.

- 10K ohm resistors

Figure 4.2.4 shows the 10K ohm resistors used in this final year project. The 10K ohm resistor is used to as pull-down resistor for Force Sensitive Resistor circuit.

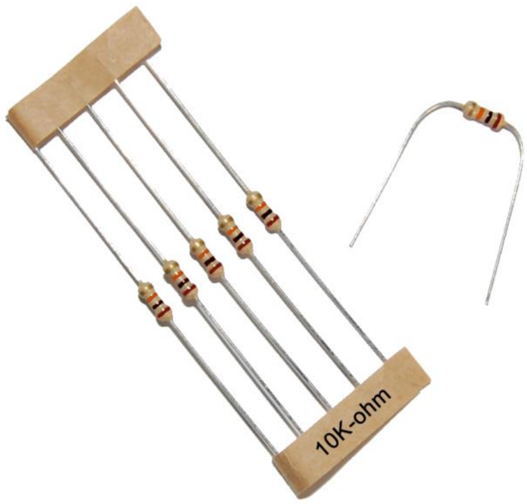

Figure 4.2.4: 10K ohm resistors

- Arduino Stackable Female Header

The Arduino stackable female header is used in this final year project as shown in figure 4.2.5. The usage of this female header is used to connecting between Low-Cost Smart Pillow Sensor Board and Arduino Uno. The female header is soldered into the Low-Cost Smart Pillow Sensor Board to let the board can stack on top of the Arduino Uno.

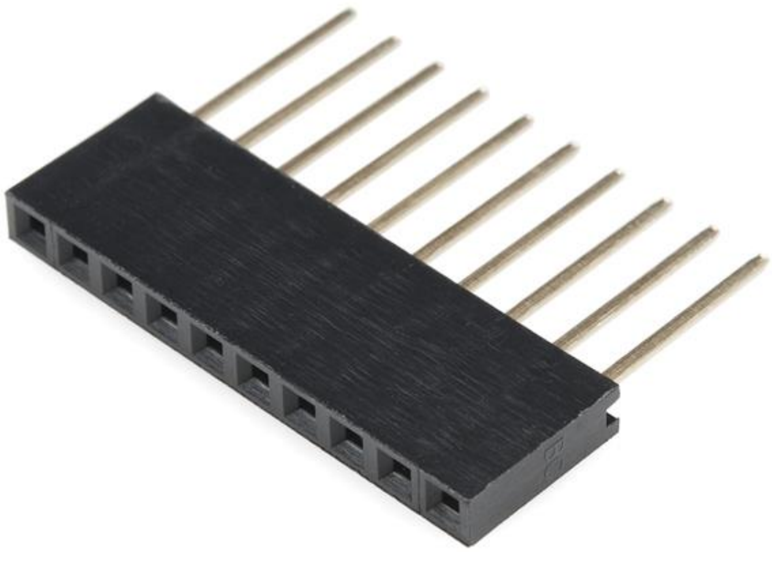

Figure 4.2.5: Arduino Stackable Female Header

- The Low-Cost Smart Pillow Sensor Board (PCB)

The schematic and the PCB layout of the Low-Cost Smart Pillow Sensor Board are shown in Figure 4.2.6 and Figure 4.2.7 respectively. These diagrams are designed using the PCB design software named EAGLE. The EAGLE software will be discussed in software part. The main purpose of developing this PCB is for reduced the jumper wire that connects between the sensor node and Arduino Uno.

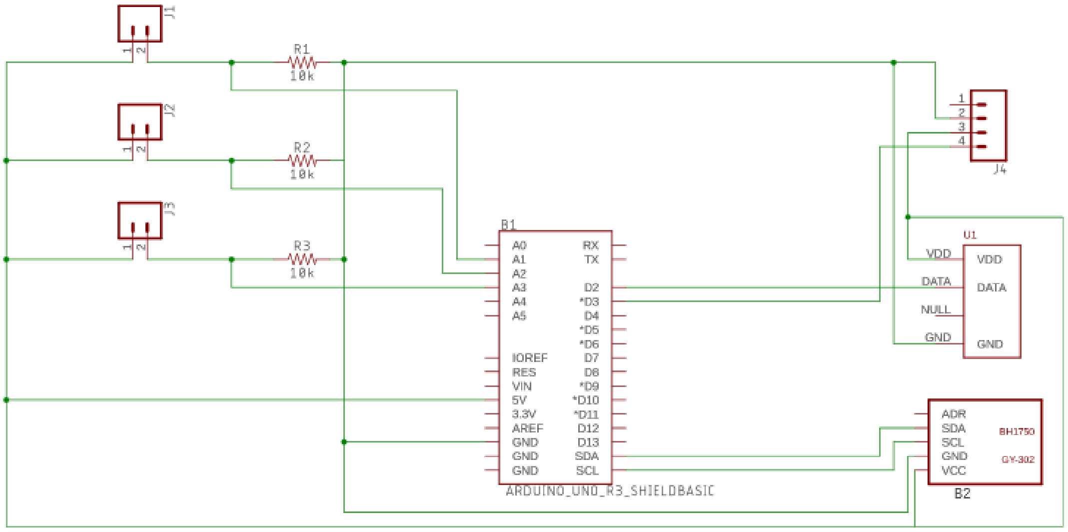

Figure 4.2.6: Schematic of Low-Cost Smart Pillow Sensor Board

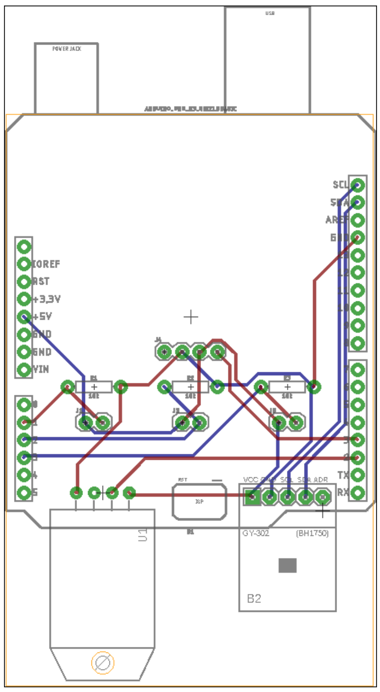

Figure 4.2.7: PCB layout of Low-Cost Smart Pillow Sensor Board

4.2.2 Development Board

The hardware that will be used in this project includes Arduino Uno board, Raspberry Pi 3, DHT22 Digital Temperature & Humidity Sensor Module, BH1750 Chip Light Intensity Light Module, Force Sensitive Resistor. Firstly, Arduino is an open-source computer hardware and software company, user community, and project that designs and manufactures single-board microcontroller and microcontroller kits for building interactive items and digital devices that can sense and control objects in the physical world. Arduino has multi of product range which is entry level, enhanced features, internet of things (IoT), Education, and Wearable. There are consist Arduino Uno and Arduino Nano for entry level, Arduino USB Host Shield and Arduino 4 Relays Shield for enhanced features, Arduino Yun and Arduino Tian for the internet of things (IoT), Arduino Gemma and Lilypad Arduino Simple for Wearable. Meanwhile, Arduino offers extra functionality by plug in the Arduino shield, it can easily superpower the project. In this project, Figure 4.2.8 is a picture and part description of Arduino Uno. Arduino Uno is chosen as one of the hardware for this project. Arduino Uno is a ATmega328P based microcontroller board. It has 6 analog inputs, 14 digital input/output, a 16 MHz quartz crystal, a USB connection, a power jack, a reset button and an ICSP header.

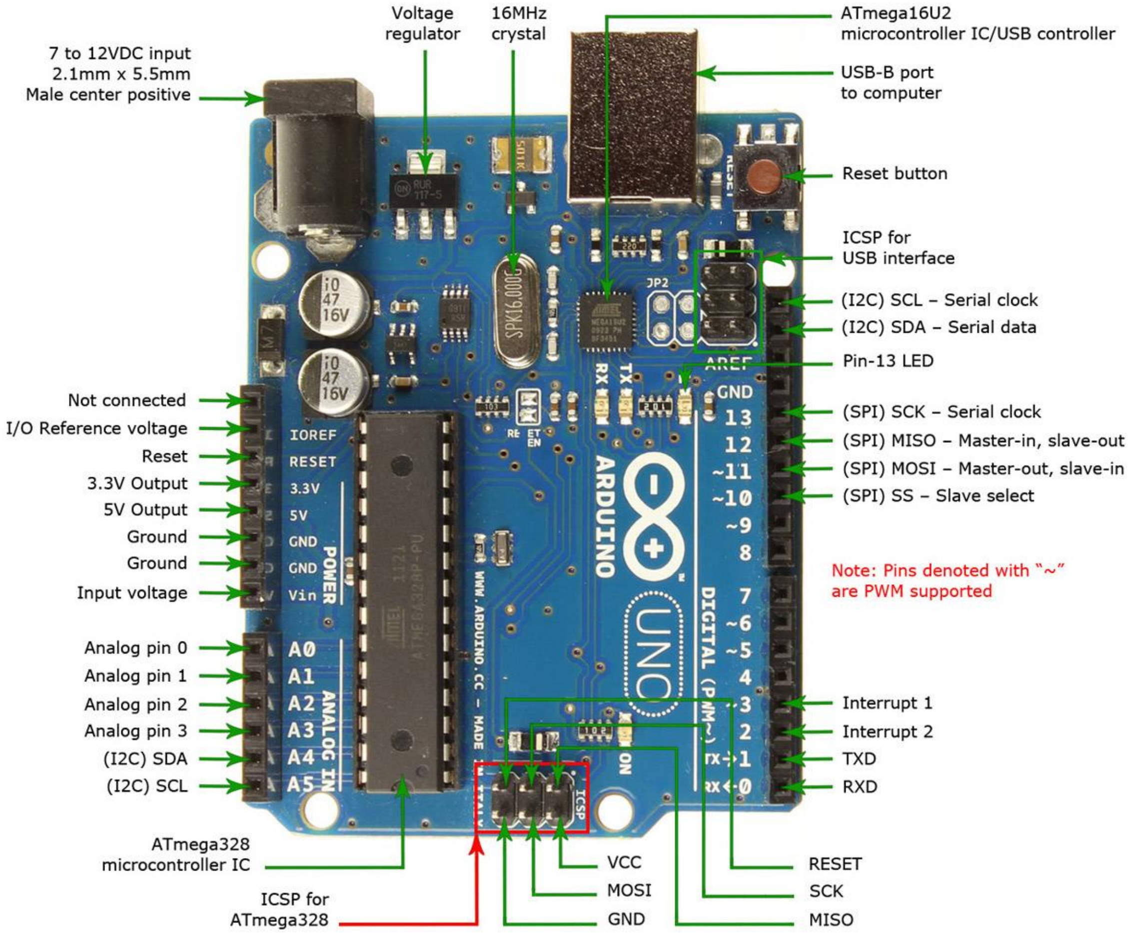

Figure 4.2.8: Arduino Uno Board and Part Description

By using Arduino Uno collect all the data from the sensor source and then transfer it to Raspberry Pi 3 upload these data to the IoT platform to store and analysis the factor that might affect user sleeping quality.

Figure 4.2.9 is a picture and part description of Raspberry Pi 3. To promote the teaching of basic computer science in schools and in developing countries. Raspberry Pi Foundation was introduced Raspberry Pi. The Raspberry Pi is a series of small single-board computers developed in the United Kingdom. The Raspberry Pi 3 is the third-generation Raspberry Pi. It replaced the Raspberry Pi 2 Model B in February 2016 and it is a first Raspberry Pi single-board computer with wireless LAN and Bluetooth connectivity.

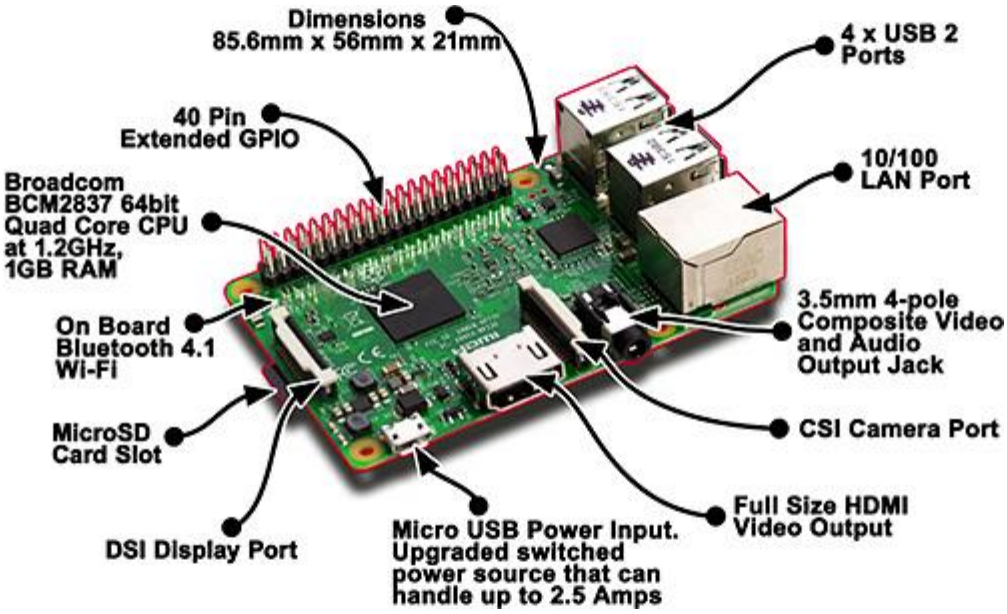

Figure 4.2.9: Raspberry Pi 3 Board and Part Description

The specification of Raspberry Pi consists of Quad Core 1.2GHz Broadcom BCM2837 64bit CPU, 1GB RAM, BCM43438 wireless LAN and Bluetooth Low Energy (BLE) onboard chip, 40-pin extended GPIO, 4 USB ports, Full size HDMI connection, CSI camera port for connecting a Raspberry Pi camera, DSI display port for connecting a Raspberry Pi touchscreen display, Micro SD port for storage data and loading your operating system, Unlike the previous generation of Raspberry Pi, upgraded Micro USB power source can up to 2.5A currently. After getting all the data, Raspberry Pi 3 will upload the data of Low-Cost Smart Pillow which collected from the sensors to the IoT platform thru internet connection. Based on the data and information that store in IoT platform, the Low-Cost Smart Pillow can determine the sleeping quality of user and based on some circumstances giving an appropriate recommendation. Users can access these data history like temperature and humidity for last night from the smartphone thru the application that offers by IoT platform.

4.2.3 Development IDE

In order to interfacing all the sensor and sensor data process, Arduino Uno and Raspberry Pi 3 is chosen as hardware for this project. For the Arduino side, this project will use Arduino integrated development environment (IDE). Figure 4.2.10 is a screenshot of Arduino IDE 1.8.5. The Arduino project provides the Arduino integrated development environment (IDE), which is a cross-platform application written in the programming language Java.

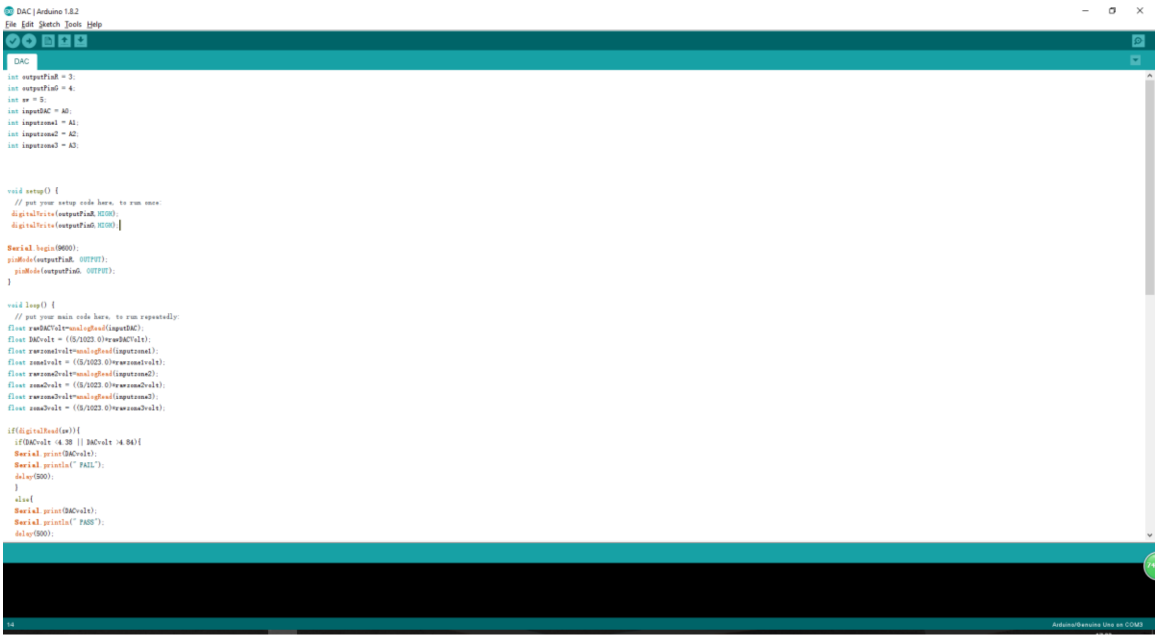

Figure 4.2.10: Screenshot of Arduino IDE 1.8.5

It invented from the IDE for the languages Processing and Wiring. It contains a message area, a text console, a toolbar with buttons for common functions and a hierarchy of operation menus. It also includes a code editor with features such as text cutting and pasting, replacing text and searching, syntax highlighting, automatic indenting, and brace matching. Arduino integrated development environment (IDE) makes it less complex to write code and upload to an Arduino board. It can run on Windows, Mac OS X, and Linux. The environment is written in Java, C, C++.

For Raspberry Pi 3 side, Raspbian operating system is used for Raspberry Pi 3. Figure 4.2.11 is a screenshot of Raspbian operating system. Raspbian is introduced by the raspberry foundation and it is a Debian-based computer operating system for Raspberry Pi single-board computer.

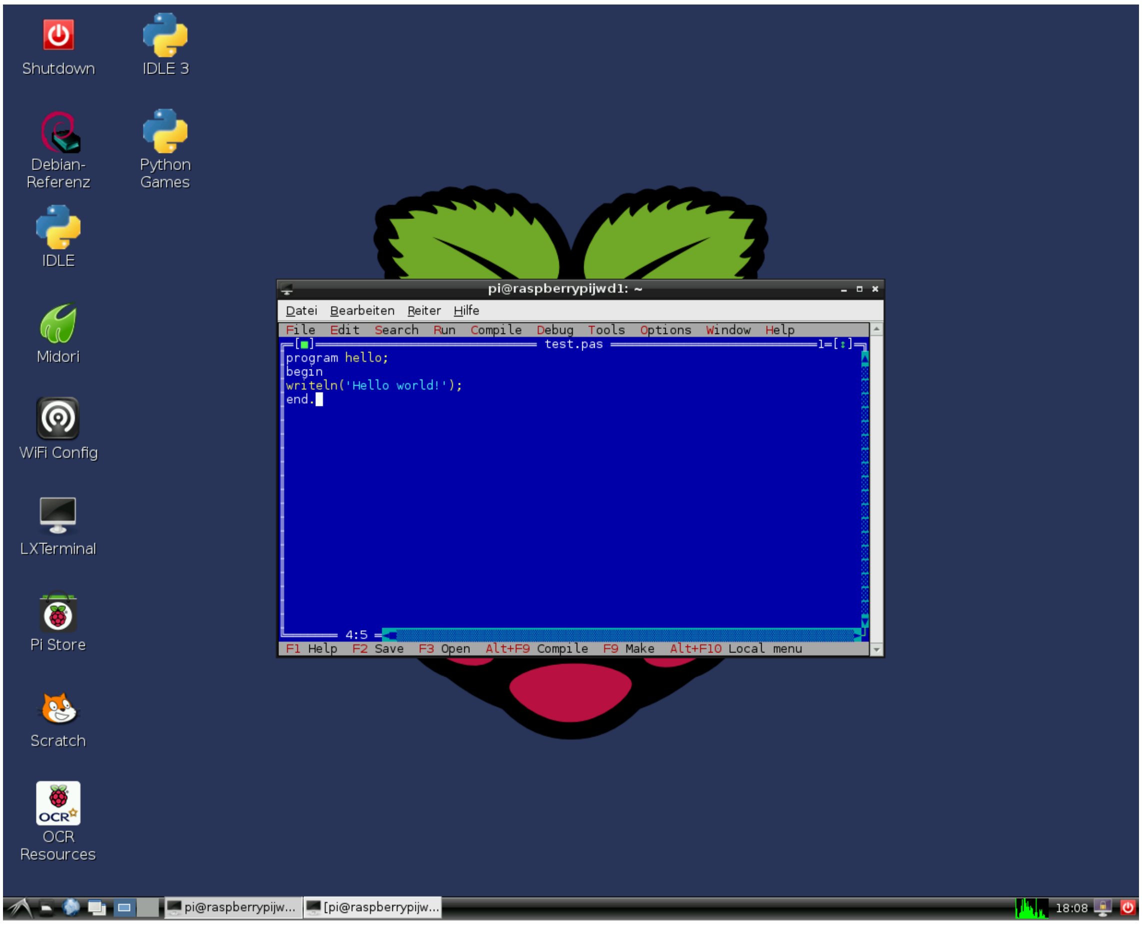

Figure 4.2.11: Screenshot of Raspbian Operating System

Raspbian Operating System has been officially provided by the Raspberry Pi Foundation since 2015, and it serves as the main operating system for the Raspberry Pi single-board computers. The initial build was completed in June 2012 and Raspbian was produced by Mike Thompson and Peter Green as an independent project.

4.2.4 PCB Development Software

The schematic and the PCB layout of the Low-Cost Smart Pillow Sensor Board is designed by EAGLE. EAGLE is a scriptable electronic design automation (EDA) desktop application with printed circuit board layout, auto-router, schematic capture, and computer-aided manufacturing (CAM) features. EAGLE stands for Easily Applicable Graphical Layout and it is developed by Autodesk Inc. In this final year project, EAGLE is use for design the schematic diagram of the PCB, and then convert to PCB layout. After finish designing the routing of PCB board, EAGLE can convert the PCB layout to Gerber file format (.gbr) for fabrication purpose. The Figure 4.2.12 is a screenshot of the EAGLE PCB software.

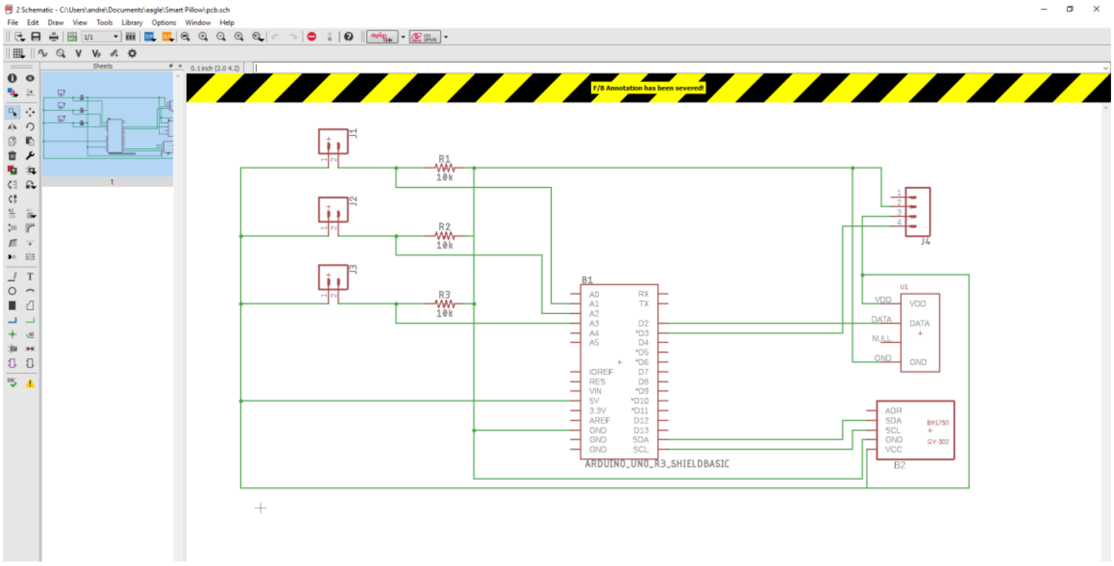

Figure 4.2.12: Screenshot of EAGLE PCB Software

4.2.5 IoT Platform

The IoT platform used in this final year project is Ubidots. Ubidots were born as a private engineering services enterprise in 2012, Ubidots specialized in connected hardware and software to monitor and control remotely thru internet connection. In 2018, Ubidots introduced the Ubidots for Education platform to give IoT enthusiast and students a place to develop, create, test, study, and discover the fascination of Internet of things that changed our life. Figure 4.2.13 is a screenshot of Ubidots IoT Platform.

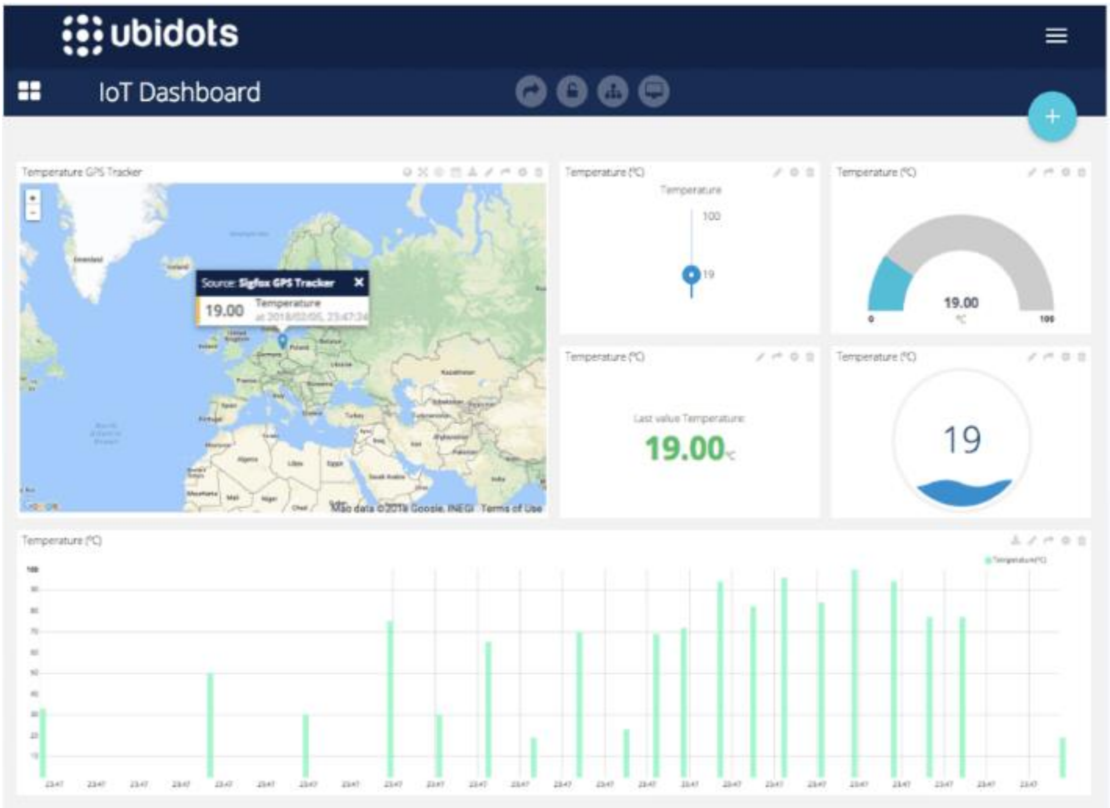

Figure 4.2.13: Screenshot of Ubidots IoT Platform

In this final year project, Ubidots is acts like an online database for storing the sensor data of Low-Cost Smart Pillow. Besides that, Ubidots provide the GUI which is the customizable dashboard use like display the information like sleep duration of the user, history temperature and humidity data, it can also display the sleeping quality and appropriate recommendation on it. Not only that, Ubidots offer the smartphone application that enables user view the data of Low-Cost Smart Pillow directly in the smartphone. Figure 4.2.14 is the screenshot of Ubidots smartphone application.

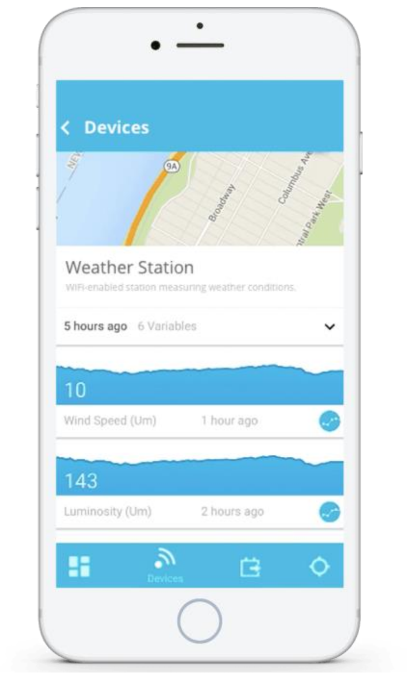

Figure 4.2.14: Screenshot of Ubidots Smart Phone Application

4.2.6 Programming Language

In this final year project, Python is the programming language that Raspberry Pi uses. Figure 4.2.15 is a screenshot of Python programming. Python is used in a wide variety of application. It is also the main programming language that Raspberry Pi is designed to use.

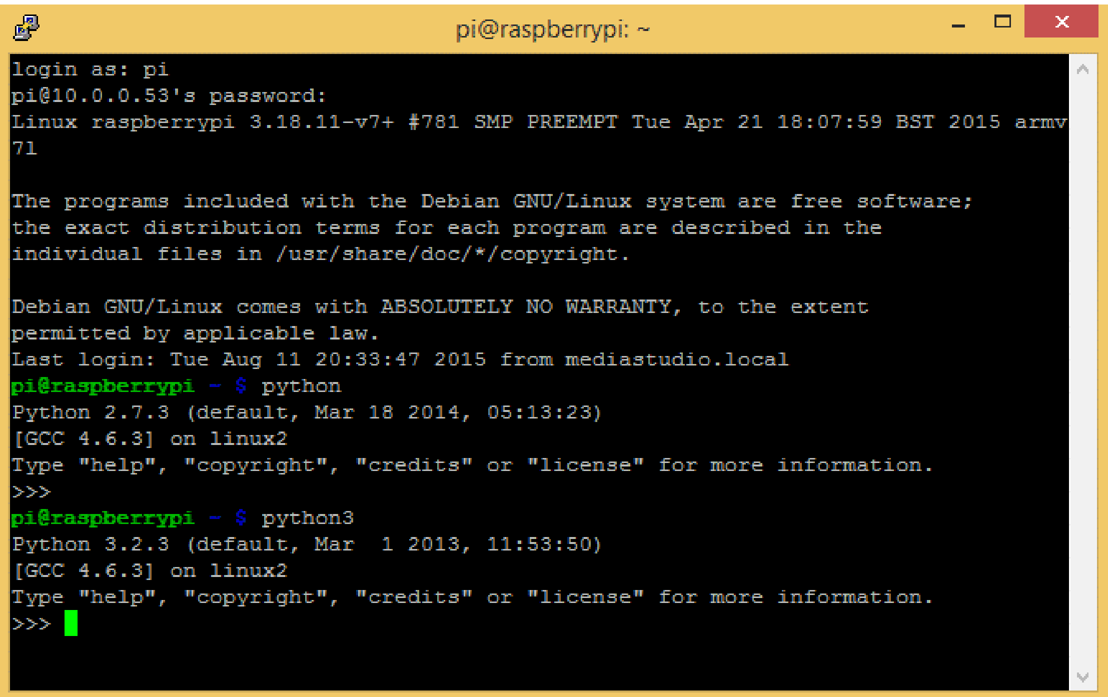

Figure 4.2.15: Screenshot of Python Programming

The advantage of Python language is excellent for beginners, highly scalable, yet superb for experts, suitable for large projects as well it can be fit to a small one, portable, cross-platform, stable and mature and it has a lot powerful standard libraries.

Meanwhile, javascript is one of the programming language used in this final year project. In this final year project, javascript is used to display the sleeping quality and recommendation on the HTML canvas that offers by IoT platform. Figure 4.2.16 is a screenshot of javascript programming.

Figure 4.2.16: Screenshot of JavaScript Programming

Chapter 5: Implementation and Testing

After implementing the hardware device and the software, some tests are done to verify and test the functionalities of the Low-Cost Smart Pillow.

5.1 Final Product

The final hardware implementation part of the text entry system is shown in Figure 5.1.1 below.

Figure 5.1.1: The entire hardware of the Low-cost Smart Pillow

5.2 Test Cases

A test case is a set of variables or conditions under which a developer will decide whether a system works properly. The process of developing test cases can also help discover problems in the requirements or design of a system. Table 5.1.1 show the test plan for the Low-Cost Smart Pillow.

No	Test Case	Details
1	Power on	Plug in power supply for turn on the Low-Cost Smart Pillow.
2	Start the sleeping process mode	Click the sleep inactive button Low-Cost Smart Pillow will start the sleeping process mode.
3	Stop the sleeping process mode	Click the sleep active button Low-Cost Smart Pillow will stop the sleeping process mode.
4	Power off	Click the power button Low-Cost Smart Pillow will be turning off.

Table 5.1.1: Test plan for the Low-Cost Smart Pillow

5.2.1 Test Cases 1: Power on

To complete the test case 1, a power source is required, any 5v power source is compatible with the Low-Cost Smart Pillow, meaning that we can use Laptop USB port, portable charger, even the wall plug to power this Low-Cost Smart Pillow. The details and the result of the test case 1 are displayed in Table 5.2.1 and Figure 5.2.1 below respectively.

Test Case	Expected Result	Actual Result
Power on	Low-Cost Smart Pillow is able to power on, online status indicator in Ubidots are turned green.	Low-Cost Smart Pillow is able to power on, online status indicator in Ubidots are turned green.

Table 5.2.1: The details of Test Case 1

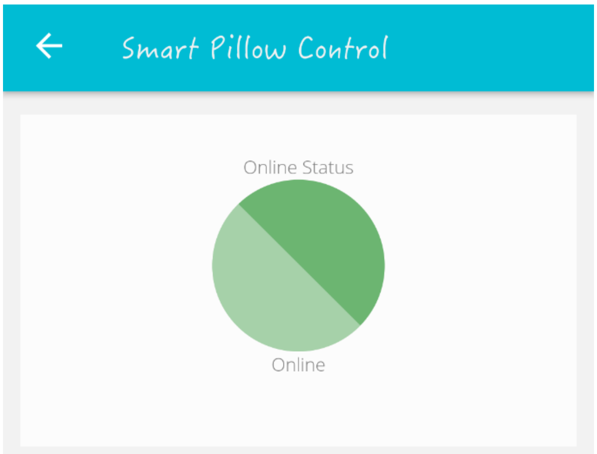

Figure 5.2.1: Online status indicator in Ubidots are turned green

5.2.2 Test Cases 2: Start the sleeping process mode

To complete the test case 2, before user going to sleep, the user must click the sleep inactive button in order to control the Low-Cost Smart Pillow enter the sleeping process mode. The details and the result of the test case 2 are displayed in Table 5.2.2 and Figure 5.2.2 below respectively.

Test Case	Expected Result	Actual Result
Start the sleeping process mode	Low-Cost Smart Pillow are starting to collect the sensor data, the power and MMC LED of Low-Cost Smart Pillow turned off.	Low-Cost Smart Pillow are starting to collect the sensor data, the power and MMC LED of Low-Cost Smart Pillow turned off.

Table 5.2.2: The details of Test Case 2

Figure 5.2.2: Power and MMC LED of Low-Cost Smart Pillow turned off

<u>5.2.3 Test Cases 3: Stop the sleeping process mode</u>

To complete the test case 3, once the user wakes up, the user must click the sleep active button in order to control the Low-Cost Smart Pillow exit the sleeping process mode. The details and the result of the test case 2 are displayed in Table 5.2.3 and Figure 5.2.3 below respectively.

Test Case	Expected Result	Actual Result
Stop the sleeping process mode	Low-Cost Smart Pillow are stop collect the sensor data, and upload all the calculated data to the Ubidots, the power of Low-Cost Smart Pillow is blinking.	Low-Cost Smart Pillow are stop collect the sensor data, and upload all the calculated data to the Ubidots, the power of Low-Cost Smart Pillow is blinking.

Table 5.2.3: The details of Test Case 3

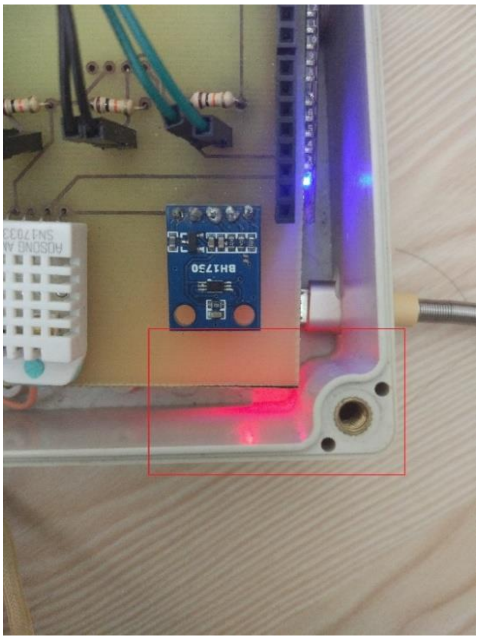

Figure 5.2.3: Power LED of Low-Cost Smart Pillow is blinking

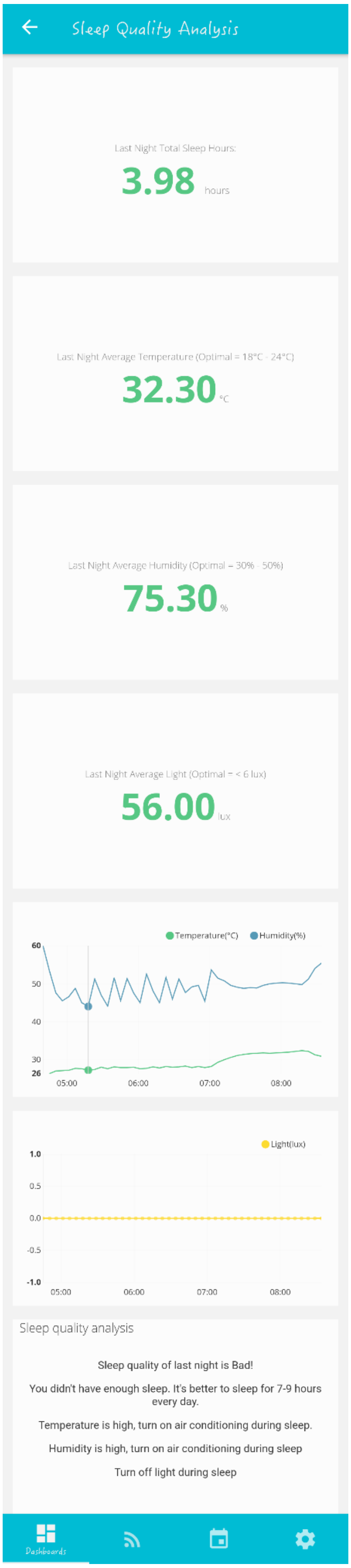

Figure 5.2.4: Sleeping data are uploaded to Ubidots

5.2.4 Test Cases 4: Power off

To complete the test case 4, once the red LED are blinking that's mean the Low-Cost Smart Pillow is ready for shut down, to shut down user required to click the power button in order to remotely shut down the Low-Cost Smart Pillow. The details and the result of the test case 2 are displayed in Table 5.2.4 and Figure 5.2.4 below respectively.

Test Case	Expected Result	Actual Result
Power off	Low-Cost Smart Pillow will shut down. Online status indicator in Ubidots is turned dark.	Low-Cost Smart Pillow will shut down. Online status indicator in Ubidots is turned dark.

Table 5.2.4: The details of Test Case 4

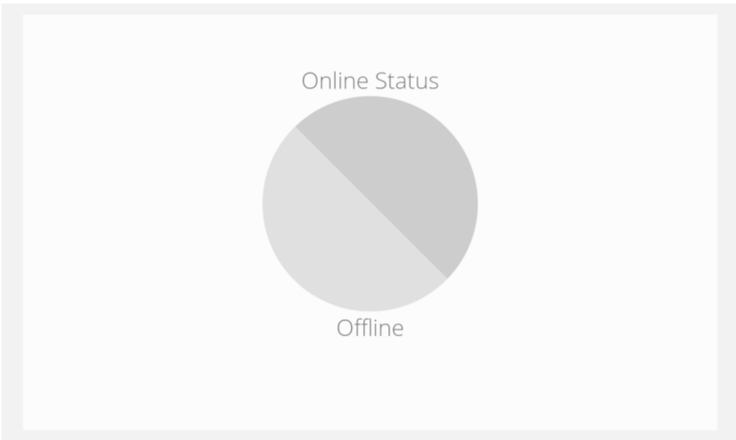

Figure 5.2.3: Online status indicator in Ubidots are turned dark

5.3 Discussion of sleep quality classification

In this final year project, sleep quality is classified for 3 stages, which is good sleep quality, moderate sleep quality, and bad sleep quality. The sleep quality is determined by 5 parameters. They are total sleep duration, average temperature, average humidity, average light intensity, amount of user toss and turn during the sleeping. According to (Kittredge, 2018), "Adults only need 7 to 9 hours of sleep", therefore the optimal total sleep duration we chose is 7 – 9 hours. Besides that, "the ideal temperature for persons to sleep comfortably is between 18 and 24 degrees Celsius" according to (Foo, 2016), so the optimal temperature we chose is 18 to 24 Celsius. Meanwhile, according to (Carey, 2011), "humidity levels of the bedroom should be about range 30-50%, with the ideal hovering at 45 percent.". Thence, the optimal humidity levels we chose is 30-50%. Not only that, according to (Perri, 2017), "Standard lux readings in a house are about 300-500, but during the hours before sleep, it would be less than 180. After turn out the lights, it would not be more than 5.". Therefore, the optimal light intensity we chose is not more than 5 lux. Last but not least, "Most of us change sleeping positions about 20 times throughout the night. This amount of rolling in your sleep is considered normal and won't negatively affect your sleep or health." according to (Chole, 2016). Therefore, the optimal amount of user toss and turn during their sleep we chose is not more than 20.

For the recommendation part, it will come out recommendation once the average data from each for the parameter does not meet the criteria which defined at above. Table 5.3.1 shows the how the sleep quality classification is defined.

The amount of parameter meets the criteria	Sleep quality
0	Bad
1	Bad
2	Moderate
3	Moderate
4	Good
5	Good

Table 5.3.1: How the sleep quality classification is defined

For the example, the user only sleep around 5 hours, In the dashboard of Sleep Quality Analysis, it will display "You didn't have enough sleep. It's better to sleep for 7-9 hours every day." to remind the user didn't have enough sleep.

5.4 Strength and weakness of the system

In this final year project, the strength of Low-Cost Smart Pillow is low-cost. Since the hardware it uses to developing Low-Cost Smart Pillow is cheaper which compare the selling price of another smart pillow in the market. The second strength is portable, the Low-Cost Smart Pillow can be powered by the portable charger and it communicates with IoT platform via Wi-Fi. Therefore, the user can use the Low-Cost Smart Pillow everywhere with a piece of mind. Third Strength is easy to use, the Low-Cost smart pillow is only having 2 control buttons for it, one is sleep active button for start the data collection phase, another one is power button which can remotely turn off the Low-Cost Smart Pillow. It can be controlled by using Google Assistant voice command as well.

For the weakness part, the biggest weakness for Low-Cost Smart Pillow is the hardware which located on the pillow is easy to damage. Thought out this development, we realized that the hardware located on the pillow which is the Force sensitive resistor we chose are easy to damage. Therefore, this Low-Cost Smart Pillow needs well care while user using it. The second weakness is a stable internet connection is required since this Low-Cost Smart Pillow is connected to IoT platform, therefore the stable internet connection is required for the Low-Cost Smart Pillow work.

5.5 Future Enhancement

Future improvement can be made to solve the weakness of the system highlighted above. One of the enhancements can be made is change the hardware located on the pillow which is Force Sensitivity Resistor to the one is more durable or even can be embedded into the pillow. With this enhancement, it's can be solved the easy damage issue mentioned above. The second enhancement is built a temporary database for storing the data that needed upload to IoT platform while the internet connection is not available, with the temporary database, the data needed upload to IoT platform can be saved to the temporary database and resume upload when the internet connection is available. Its enhancement can solve the weakness of stable internet connection is required for Low-Cost Smart Pillow mentioned above.

CHAPTER 6: Conclusion

6.1 Project Review

Throughout the process of this final year project development, many of the learnt knowledge and skill had been applied. Foundation and awareness of course subjects such as Embedded System Design and Embedded Architecture and Computing had assisted me a lot throughout this project development.

This project also provided a great opportunity to learn about programming using Arduino platform and Python programming language. This knowledge and experience granted will be useful for future study or further career.

During the hardware implementation of the Low-Cost Smart Pillow, there are many challenges and issues happened. One of the issues is about the sensor components. Some components such as the sound sensor are malfunction, therefore, this sound sensor can't be utilized as a one of the sensors for a Low-Cost Smart Pillow. Hence, it needs check functionality before soldering to PCB board. Another issue is soldering issue, some of the components are not functioning after solder. Hence, the Low-Cost Smart Pillow is no work properly and troubleshooting is required for this problem, it need to check the solder of component one by one.

Furthermore, the development of the Low-Cost Smart Pillow sensor board become one of the challenges. The thought of development of the Low-Cost Smart Pillow Sensor Board instead of using the ordinary breadboard and jumper wires is because Low-Cost Smart Pillow Sensor Board which build from concept Arduino Shield is free of jumper wire and ease for carrying. This is to make the Low-Cost Smart Pillow less wire and simple. Due to zero knowledge of developing the Arduino Shield, some studies are applied on how to design an Arduino Shield.

After that, the cost of the Low-Cost Smart Pillow is also taken into contemplation and it should be inexpensive. The objective of this project is to provide a Low-Cost Smart Pillow that able to trace and record the sleeping data of users. Hence, the objective is fully achieved because the Low-Cost Smart Pillow is relatively low-cost compared to another smart pillow in the research papers. As a conclusion, the proposed of the Low-Cost Smart Pillow will give the second option for those need a smart pillow to improve their sleeping quality.

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Appendices

Arduino Code

```
#include <DHT.h>;

#include <Wire.h>

#include <BH1750.h>


//Constants

#define DHTPIN 2     // what pin we're connected to

#define DHTTYPE DHT22   // DHT 22  (AM2302)

DHT dht(DHTPIN, DHTTYPE); //// Initialize DHT sensor for normal 16mhz Arduino

BH1750 lightMeter;

//Variables

int chk;

float hum;  //Stores humidity value

float temp; //Stores temperature value

uint16_t lux; //Stores light value

uint16_t lux_cover; //Stores light value while put on cover

 /* FSR testing sketch.


Connect one end of FSR to power, the other end to Analog 0.

Then connect one end of a 10K resistor from Analog 0 to ground


For more information see www.ladyada.net/learn/sensors/fsr.html */


int fsrPin1 = 1;     // the FSR and 10K pulldown are connected to a1

int fsrReading1;     // the analog reading from the FSR resistor divider

int fsrVoltage1;     // the analog reading converted to voltage

unsigned long fsrResistance1;  // The voltage converted to resistance, can be very big
so make "long"

unsigned long fsrConductance1;
```

```
boolean fsr1;

int fsrPin2 = 2;     // the FSR and 10K pulldown are connected to a2
int fsrReading2;     // the analog reading from the FSR resistor divider
int fsrVoltage2;     // the analog reading converted to voltage
unsigned long fsrResistance2;  // The voltage converted to resistance, can be very big
so make "long"
unsigned long fsrConductance2;
boolean fsr2;

int fsrPin3 = 3;     // the FSR and 10K pulldown are connected to a3
int fsrReading3;     // the analog reading from the FSR resistor divider
int fsrVoltage3;     // the analog reading converted to voltage
unsigned long fsrResistance3;  // The voltage converted to resistance, can be very big
so make "long"
unsigned long fsrConductance3;
boolean fsr3;
int i=0;

void setup()
{

   Serial.begin(115200);
   dht.begin();
  // Initialize the I2C bus (BH1750 library doesn't do this automatically)
  // On esp8266 devices you can select SCL and SDA pins using Wire.begin(D4, D3);
   Wire.begin();
   lightMeter.begin();
   pinMode(5,OUTPUT);
   pinMode(3,OUTPUT);
   pinMode(8,OUTPUT);
```

```
    pinMode(11,OUTPUT);

}
void loop()
{
  //Read data and store it to variables hum and temp
    hum = dht.readHumidity();
    temp= dht.readTemperature();
    lux = lightMeter.readLightLevel();
  fsrReading1 = analogRead(fsrPin1);
  fsrReading2 = analogRead(fsrPin2);
  fsrReading3 = analogRead(fsrPin3);

  // analog voltage reading ranges from about 0 to 1023 which maps to 0V to 5V (= 5000mV)
  fsrVoltage1 = map(fsrReading1, 0, 1023, 0, 5000);
  fsrVoltage2 = map(fsrReading2, 0, 1023, 0, 5000);
  fsrVoltage3 = map(fsrReading3, 0, 1023, 0, 5000);



  if (fsrVoltage1 == 0) {
    fsr1 = 0;
    fsrConductance1 = 0;
  } else {
    // The voltage = Vcc * R / (R + FSR) where R = 10K and Vcc = 5V
    // so FSR = ((Vcc - V) * R) / V        yay math!
    fsrResistance1 = 5000 - fsrVoltage1;     // fsrVoltage is in millivolts so 5V = 5000mV
    fsrResistance1 *= 10000;                // 10K resistor
    fsrResistance1 /= fsrVoltage1;
```

```
    fsrConductance1 = 1000000;           // we measure in micromhos so
    fsrConductance1 /= fsrResistance1;
    if (fsrConductance1 < 15) {
     fsr1 = 0;
    }
    else {
     fsr1 = 1;
    }

  }

  if (fsrVoltage2 == 0) {
    fsr2 = 0;
    fsrConductance2 = 0;
  } else {
    // The voltage = Vcc * R / (R + FSR) where R = 10K and Vcc = 5V
    // so FSR = ((Vcc - V) * R) / V        yay math!
    fsrResistance2 = 5000 - fsrVoltage2;     // fsrVoltage is in millivolts so 5V =
5000mV
    fsrResistance2 *= 10000;                // 10K resistor
    fsrResistance2 /= fsrVoltage2;

    fsrConductance2 = 1000000;           // we measure in micromhos so
    fsrConductance2 /= fsrResistance2;
    if (fsrConductance2 < 15) {
     fsr2 = 0;
    }
    else {
     fsr2 = 1;
    }
```

```
 }

 if (fsrVoltage3 == 0) {
   fsr3 = 0;
   fsrConductance3 = 0;
 } else {
   // The voltage = Vcc * R / (R + FSR) where R = 10K and Vcc = 5V
   // so FSR = ((Vcc - V) * R) / V        yay math!
   fsrResistance3 = 5000 - fsrVoltage3;     // fsrVoltage is in millivolts so 5V =
5000mV
   fsrResistance3 *= 10000;                // 10K resistor
   fsrResistance3 /= fsrVoltage3;

   fsrConductance3 = 1000000;           // we measure in micromhos so
   fsrConductance3 /= fsrResistance3;
   if (fsrConductance3 < 15) {
    fsr3 = 0;
   }
   else {
    fsr3 = 1;
   }

 }
   if(fsr1 == 1 && fsr2 == 1)
     {
       if(fsrConductance1 < fsrConductance2)
       {
         fsr1 = 0;
       }
       else {
```

```
      fsr2 = 0;
    }
  }

  if(fsr2 == 1 && fsr3 == 1)
  {
    if(fsrConductance2 < fsrConductance3)
    {
      fsr2 = 0;
    }
    else {
      fsr3 = 0;
    }
  }

  if(fsr1 == 1 && fsr3 == 1)
  {
    if(fsrConductance1 < fsrConductance3)
    {
      fsr1 = 0;
    }
    else {
      fsr3 = 0;
    }
  }

   if(fsr1 == 1 && fsr2 == 1 && fsr3 == 1)
  {
    if(fsrConductance1 < fsrConductance2 && fsrConductance3 < fsrConductance2)
    {
```

```
      fsr1 = 0;
      fsr2 = 1;
      fsr3 = 0;
    }
    else if(fsrConductance1 < fsrConductance3 && fsrConductance2 <
fsrConductance3)
    {
      fsr1 = 0;
      fsr2 = 0;
      fsr3 = 1;
    }
    else {
      fsr1 = 1;
      fsr2 = 0;
      fsr3 = 0;
    }
  }

  Serial.println(fsr1);
  Serial.println(fsr2);
  Serial.println(fsr3);
  sensor();
  delay(1900);

}//--------------- End of loop() loop ---------------------

void sensor (void)
{
  //Print temp and humidity values to serial monitor
  Serial.println(hum);
```

```
   Serial.println(temp);
   lux_cover = (lux * 1.12);
   Serial.println(lux_cover);
}
```

Rapberry Pi Script (smart_pillow.py)

```
import serial
import datetime,time
from datetime import date
from time import sleep
import time
import mysql.connector
import os
import thread
import sys
import threading
from ubidots import ApiClient
arduino = serial.Serial('/dev/ttyUSB0',115200)
now = datetime.datetime.now()
start_time_string = "07:59:59"
start_datetime = datetime.datetime.strptime(start_time_string, "%H:%M:%S")
start_datetime = now.replace(hour=start_datetime.time().hour,
minute=start_datetime.time().minute, second=start_datetime.time().second,
microsecond=0)
end_time_string = "08:00:59"
end_datetime = datetime.datetime.strptime(end_time_string, "%H:%M:%S")
```

```
end_datetime = now.replace(hour=end_datetime.time().hour,
minute=end_datetime.time().minute, second=end_datetime.time().second,
microsecond=0)

time_correct = 0

second = 0

fsr_second = 0

first_entry = 1

flip_counter = -1

current_fsr = 5

previous_fsr = 5

humidity_avg = []

temperature_avg = []

lux_avg = []

total_humidity_avg = float(0)

total_temperature_avg = float(0)

total_lux_avg = float(0)

sleepstatus_ok = 0

api = ApiClient(token='A1E-O6dEo3wPkD793v0auMENGXcEipNq8L')

online_v = api.get_variable('5b746123c03f9718993ecb15')

online_v.save_value({'value': 1.0})

power_v = api.get_variable('5b479bf8c03f9736cfe8ae04')

power_v.save_value({'value': 0.0})

sleepstatus_v = api.get_variable('5b47943dc03f972f4c6789a6')

sleepstatus_v.save_value({'value': 0.0})

sleepstatus = sleepstatus_v.get_values(1)
```

```
sleepstatusresult = sleepstatus_v.get_values(1)

if sleepstatus[0]['value'] == 0.0:

    sleepstatus_ok = 1

else:

    sleepstatus_ok = 0


def upload():

        ubidot_timestamp = ubidot_rtc

        humidity_v = api.get_variable('5b3dd14dc03f9716a0573199')

        temperature_v = api.get_variable('5b3dd0dec03f9715ba33a9eb')

        lux_v = api.get_variable('5b3dd163c03f9716bdcc3864')

        humidity_v.save_value({'value': five_humidity,'timestamp': ubidot_timestamp})

        ##sleep(0.5)

        temperature_v.save_value({'value': five_temperature,'timestamp':
ubidot_timestamp})

        ##sleep(0.5)

        lux_v.save_value({'value': five_lux,'timestamp': ubidot_timestamp})

        exit()


def getsleep_status():

        global sleepstatusresult

        sleepstatusresult = sleepstatus_v.get_values(1)

        exit()
```

```
def upload_total():
        ubidot_timestamp = ubidot_rtc
        total_sleep_v = api.get_variable('5b69e284c03f97106326485c')
        total_humidity_avg_v = api.get_variable('5b69ef95c03f971dcc16bf45')
        total_temperature_avg_v = api.get_variable('5b69ef9fc03f971de9e56a18')
        total_lux_avg_v = api.get_variable('5b69ef8bc03f971d671a7469')
        flip_v = api.get_variable('5b7807c8c03f9733dd2e5855')
        total_sleep_v.save_value({'value': elapsed,'timestamp': ubidot_timestamp})
        total_humidity_avg_v.save_value({'value': total_humidity_avg,'timestamp':
ubidot_timestamp})
        total_temperature_avg_v.save_value({'value': total_temperature_avg,'timestamp':
ubidot_timestamp})
        total_lux_avg_v.save_value({'value': total_lux_avg,'timestamp':
ubidot_timestamp})
        flip_v.save_value({'value': flip_counter,'timestamp': ubidot_timestamp})
        exit()


while True:
    t1 = threading.Thread(target=getsleep_status)
    t1.start()
    if sleepstatus_ok == 1:
        if sleepstatusresult[0]['value'] == 1.0:
            if (time_correct == 0):
                cmddate = "\"$(wget -qSO- --max-redirect=0 google.com 2>&1 | grep Date:
| cut -d' ' -f5-8)Z\""
```

```
        os.system("sudo date -s" + cmddate)
        currentDT = datetime.datetime.now()
        if (currentDT < start_datetime or currentDT > end_datetime):
            time_correct = 1
            cmd = "echo 0 | sudo tee /sys/class/leds/led0/brightness"
            os.system(cmd)
            cmd = "echo 0 | sudo tee /sys/class/leds/led1/brightness"
            os.system(cmd)
            start = time.time()
    else:
        first_entry = 0
        currentDT = datetime.datetime.now()
        ubidot_rtc = time.mktime(currentDT.timetuple())
        ubidot_rtc = ubidot_rtc * 1000
        ubidot_rtc = int (ubidot_rtc)
        #print currentDT
        fsr1 = arduino.readline()
        fsr2 = arduino.readline()
        fsr3 = arduino.readline()
        humidity = arduino.readline()
        temperature = arduino.readline()
        lux = arduino.readline()
        fsr1 = int(fsr1)
        sleep(0.1)
```

```
fsr2 = int(fsr2)
fsr3 = int(fsr3)
if (fsr_second == 12 or fsr_second == 0):
    previous_fsr = current_fsr
    if (fsr1 == 0 and fsr2 == 0 and fsr3 == 0):
        current_fsr = previous_fsr
    elif (fsr1 == 1):
        current_fsr = 1
    elif (fsr2 == 1):
        current_fsr = 2
    elif (fsr3 == 1):
        current_fsr = 3
    if (current_fsr != previous_fsr):
        flip_counter = flip_counter + 1
    fsr_second = 2

if (second == 302 or second == 0):
    second = 4
    five_humidity = float(humidity)
    five_temperature = float(temperature)
    five_lux = float(lux)
    humidity_avg.append(five_humidity)
    temperature_avg.append(five_temperature)
    lux_avg.append(five_lux)
```

```
            t2 = threading.Thread(target=upload)
            t2.start()
        else:
            second = second + 2
            fsr_second = fsr_second + 2
        sleep(1.9)

    elif sleepstatusresult[0]['value'] == 0.0 and first_entry == 0:
        end = time.time()
        elapsed = end - start
        elapsed = float(elapsed)
        elapsed = float(round(elapsed, 0))
        elapsed = float(elapsed/60/60)
        elapsed = str(round(elapsed, 3))
        total_humidity_avg = sum(humidity_avg)
        total_humidity_avg = total_humidity_avg / len(humidity_avg)
        total_temperature_avg = sum(temperature_avg)
        total_temperature_avg = total_temperature_avg / len(temperature_avg)
        total_lux_avg = sum(lux_avg)
        total_lux_avg = total_lux_avg / len(lux_avg)
        t3 = threading.Thread(target=upload_total)
        t3.start()
        os.system("python /home/pi/power.py &")
        sys.exit()
```

```
    else:
        sleep(1)
```

Rapberry Pi Script (power.py)

```
from ubidots import ApiClient
from time import sleep
import thread
import threading
import os
api = ApiClient(token='A1E-O6dEo3wPkD793v0auMENGXcEipNq8L')
power_v = api.get_variable('5b479bf8c03f9736cfe8ae04')
power_v.save_value({'value': 1.0})
powerstatusresult = power_v.get_values(1)
power = power_v.get_values(1)
cmd = "echo heartbeat | sudo tee /sys/class/leds/led1/trigger"
os.system(cmd)
if power[0]['value'] == 1.0:
  power_ok = 1


def getpower_status():
    global powerstatusresult
    powerstatusresult = power_v.get_values(1)
    exit()


while True:
```

```python
    if power_ok == 1:

        t3 = threading.Thread(target=getpower_status)

        t3.start()

        if powerstatusresult[0]['value']== 0.0:

            os.system("sudo poweroff")

            exit()

        else:

            sleep(1)

    else:

        pass
```

Ubidots HTML canvas (HTML)

```html
<div class="box">

<p id="recommendation">Sleep quality of last night is </p>

<p id="sleep_recommendation"></p>

<p id="flip_recommendation"></p>

<p id="temp_recommendation"></p>

<p id="humidity_recommendation"></p>

<p id="light_recommendation"></p>

</div>
```

Ubidots HTML canvas (Javascript)

```javascript
var temp;

var last_temp = null;

var humidity;

var last_humidity = null;

var light;
```

```
}

var last_light = null;
var sleephour = null;
var last_sleephour = null;
var flip;
var last_flip = null;
var recommendation = $('#recommendation');
var flip_recommendation = $('#flip_recommendation');
var sleep_recommendation = $('#sleep_recommendation');
var temp_recommendation = $('#temp_recommendation');
var humidity_recommendation = $('#humidity_recommendation');
var light_recommendation = $('#light_recommendation');
var sleepquality = 0;

function getTemperature(variableId, token) {
  var url = 'https://things.ubidots.com/api/v1.6/variables/' + variableId + '/values';
  $.get(url, { token: token, page_size: 1 }, function (res) {
    if (last_temp === null ||res.results[0].value !== last_temp.value) {
      temp = res.results[0].value;
      last_temp = res.results[0].value;
      if (temp > 24){
            temp_recommendation.text("Temperature is high, turn on air conditioning during sleep.");
}
      else if (temp < 18){
```

```
            temp_recommendation.text("Temperature is low, turn on air heater during
sleep.");
}
      else{
       sleepquality = sleepquality + 20;
      }
    }
  });
}


function getHumidity(variableId, token) {
  var url = 'https://things.ubidots.com/api/v1.6/variables/' + variableId + '/values';
  $.get(url, { token: token, page_size: 1 }, function (res) {
    if (last_humidity === null ||res.results[0].value !== last_humidity.value) {
      humidity = res.results[0].value;
      last_humidity = res.results[0].value;
      if (humidity < 30){
            humidity_recommendation.text("Humidity is low, turn on humidifiers during
sleep");
}
      else if (humidity > 50){
            humidity_recommendation.text("Humidity is high, turn on air conditioning
during sleep");
}
      else{
```

```
       sleepquality = sleepquality + 20;
      }
    }
  });
}

function getLight(variableId, token) {
  var url = 'https://things.ubidots.com/api/v1.6/variables/' + variableId + '/values';
  $.get(url, { token: token, page_size: 1 }, function (res) {
    if (last_light === null ||res.results[0].value !== last_light.value) {
      light = res.results[0].value;
      last_light = res.results[0].value;
      if (light > 5){
             light_recommendation.text("Turn off light during sleep");
}
      else{
       sleepquality = sleepquality + 20;
      }
    }
  });
}

function getSleephour(variableId, token) {
  var url = 'https://things.ubidots.com/api/v1.6/variables/' + variableId + '/values';
```

```
  $.get(url, { token: token, page_size: 1 }, function (res) {
    if (last_sleephour === null ||res.results[0].value !== last_sleephour.value) {
      sleephour = res.results[0].value;
      last_sleephour = res.results[0].value;
      if (sleephour < 7){
              sleep_recommendation.text("You didn't have enough sleep. It's better to
sleep for 7-9 hours every day.");
}
      else{
       sleepquality = sleepquality + 20;
      }
    }
  });
}


function getFlip(variableId, token) {
  var url = 'https://things.ubidots.com/api/v1.6/variables/' + variableId + '/values';
  $.get(url, { token: token, page_size: 1 }, function (res) {
    if (last_flip === null ||res.results[0].value !== last_flip.value) {
      flip = res.results[0].value;
      last_flip = res.results[0].value;
      if (flip > 20){
              flip_recommendation.text("Too much toss and turn. Avoid using electronic
devices before sleep.");
}
```

```
      else{
       sleepquality = sleepquality + 20;
      }
    }
  });
}

function getallstatus(){
        if (sleepquality >= 0 && sleepquality <= 33.3)
    {
      recommendation.text("Sleep quality of last night is Bad!");
    }
        else if (sleepquality > 33.3 && sleepquality <= 66.7)
    {
      recommendation.text("Sleep quality of last night is Moderate!");
    }
        else if (sleepquality > 66.7 && sleepquality <= 100)
    {
      recommendation.text("Sleep quality of last night is Good!");
    }

}
```

```
getTemperature('5b69ef9fc03f971de9e56a18', 'A1E-
O6dEo3wPkD793v0auMENGXcEipNq8L');

getHumidity('5b69ef95c03f971dcc16bf45', 'A1E-
O6dEo3wPkD793v0auMENGXcEipNq8L');

getLight('5b69ef8bc03f971d671a7469', 'A1E-
O6dEo3wPkD793v0auMENGXcEipNq8L');

getSleephour('5b69e284c03f97106326485c', 'A1E-
O6dEo3wPkD793v0auMENGXcEipNq8L');

getFlip('5b7807c8c03f9733dd2e5855', 'A1E-
O6dEo3wPkD793v0auMENGXcEipNq8L');

setInterval(function () {

  getallstatus();

}, 2000);
```

Cost of Low-Cost Smart Pillow

Component	Price
Arduino Uno x1	RM 25
Raspberry Pi 3 x1	RM 158.58
Force Sensitive Resistor x3	RM 45.00
DHT22 Digital Temperature & Humidity Sensor x1	RM 10.00
BH1750 Chip Light Intensity Light Sensor x1	RM 3.00
Arduino Female Header 1x6 Ways x1	RM 1.00
Arduino Female Header 1x8 Ways x2	RM 2.40
Arduino Female Header 1x10 Ways x1	RM 1.50
Total	RM 259.98

Table A.1.1: Cost of Low-Cost Smart Pillow

Poster

Figure A.1.1: Poster of project

Turnitin Report

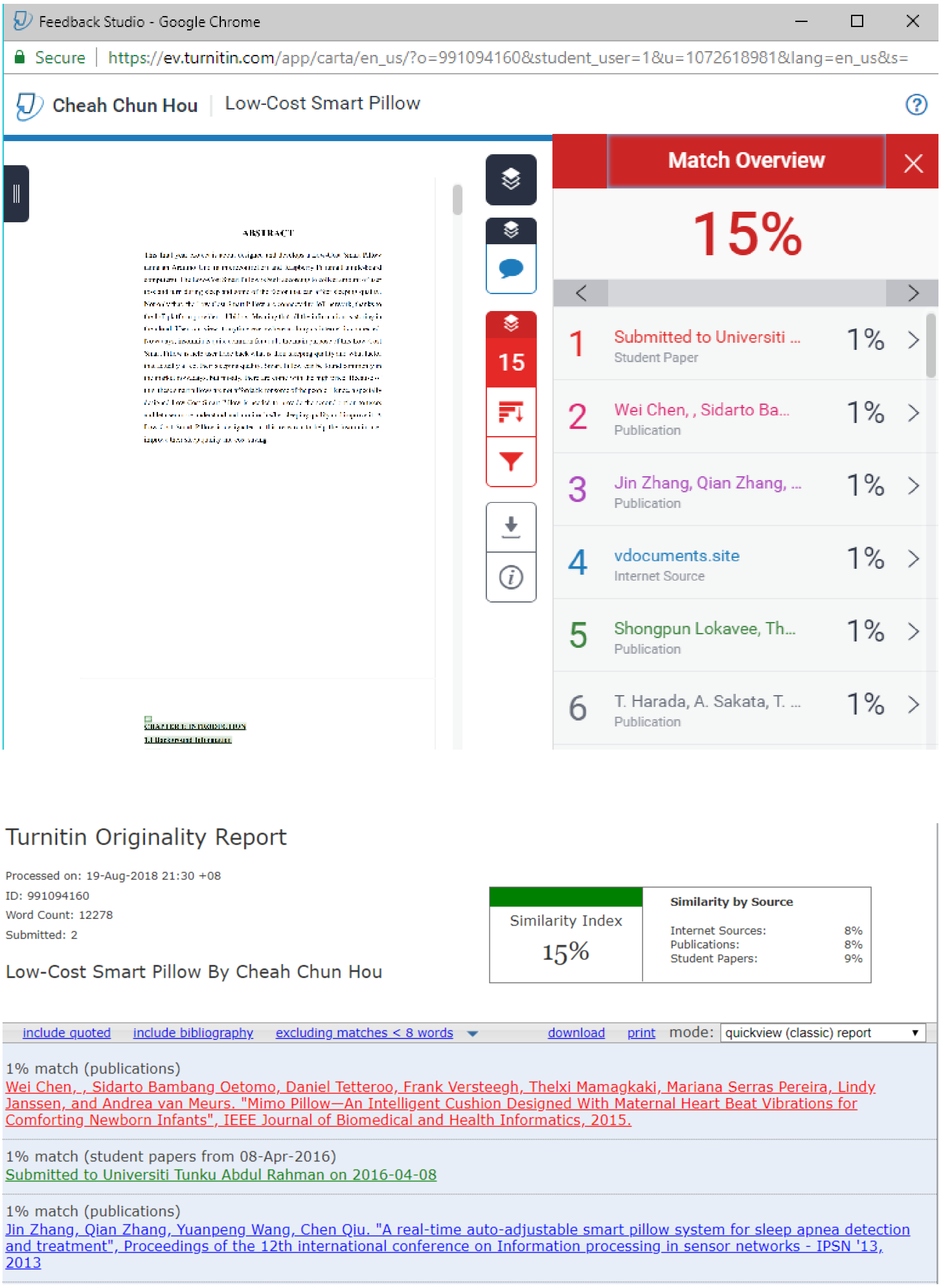

Figure A.1.2: Turnitin Report

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Form Title : Supervisor's Comments on Originality Report Generated by Turnitin for Submission of Final Year Project Report (for Undergraduate Programmes)			
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Based on the above results, I hereby declare that I am satisfied with the originality of the Final Year Project Report submitted by my student(s) as named above.

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Name: __________________________

Date: ___________________________

____
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Name: __________________________

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UNIVERSITI TUNKU ABDUL RAHMAN

FACULTY OF INFORMATION & COMMUNICATION TECHNOLOGY (KAMPAR CAMPUS)

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	Signed Report Status Declaration Form
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	Acknowledgement
	Abstract
	Table of Contents
	List of Figures (if applicable)
	List of Tables (if applicable)
	List of Symbols (if applicable)
	List of Abbreviations (if applicable)
	Chapters / Content
	Bibliography (or References)
	All references in bibliography are cited in the thesis, especially in the chapter of literature review
	Appendices (if applicable)
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