IOT-BASED SLEEP ANALYSIS USING MACHINE LEARNING TECHNIQUE

By

Wong Kah Wai

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

(Kampar Campus)

JAN 2020

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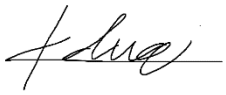

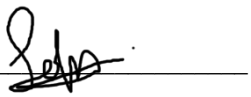

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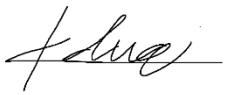

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Date : 22/4/2020

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I would like to express my sincere gratitude and thanks to my project supervisor, Mr. Teoh Shen Khang who has given me this opportunity participate and complete this project. This is a great project as there is not much IoT health related project in the market currently and thus exploring this field might bring more exposure to the IoT community.

And next I would like to thank a very important and special person in my life, Grace Foong for always give me support and love during the hard times I endure during this project. Finally, I must say thanks to all my family members and also my friends for giving me numerous ideas and work around for completing this project.

ABSTRACT

The final year project is about developing a smart pillow with IoT and machine learning capability. It utilizes a popular microprocessor readily available in the market which is the Raspberry Pi. Reason why Raspberry Pi was chosen is because it is relatively simple to use and can be obtained at a very low cost. How the system is able to categorize the sleep level is by the machine learning technology. As for the wireless capability of the device, it can be demonstrated in the Ubidots part of the system. The Ubidots function as a platform wirelessly to have full control and viewing of all the data collected by the system. Since now insomnia has been a common problem among the public, this increase the need to develop a product to overcome this problem. Even though, there are some readily available smart pillow in the market, most of them are very costly. Hence, this a low-cost smart pillow with all the latest technology has to be created to stratify the needs of the public.

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List of Abbreviations

IoT	Internet of Things
TI	Texas Instrument
RGB	Red-Green-Blue
IR	Infrared
MIC	Microphone
TOF	Time of Flight
LiPol	Lithium-ion polymer
WiFi	Wireless fidelity
SDM	System Development Method
FSR	Force Sensitive Resistor

Chapter 1: Introduction

1.1 Problem Statement

The main problem faced by human now is sleep disorder. Recent human life has been subjected to intensive heavy work load and exposed to stressful work tasks. Due to this, there has been increasing number of insomnia patients (patients that have lack of sleep or difficulty in falling asleep). This problem will then further cause more problem such as causing the increase in disabilities, inefficient work process, and unnecessary accidents that can cause serious illness. Another example of illness due to sleep disorder is sleep apnea which is a common sleep disorder characterized by the repetitive cessation of breathing during sleep and can result in various diseases, including headaches, hypertension, stroke and cardiac arrest.

1.2 Background and Motivation

1.2.1 Internet-of-Things (IoT)

In recent year(s), the term IoT short for Internet of Things has become a hot topic in most technologies field. As stated, IoT can do what previous generation technologies can not achieve which is combining the electronic and communication field together. IoT is a technology that can interconnect people and any machine that is connected to the internet. This interconnection has greatly benefit human in many ways especially in the production line. Compare to previous technology which require human-to-machine interaction, IoT allows the human to interact with the machine without needing the human to operate or touch the machine. Not only the production line, with just applying IoT into other existing technology field, a new hybrid technology can be form. Example in farming field hybrid with IoT, smart-farming a new technology is form as well as IoT in city producing smart-city. Healthcare or medical field is also a field that can benefit significantly with the apply of IoT. Healthcare has been a booming topic due to various disease that arise throughout all these years. Remote monitoring for health care is one of the field that greatly benefit from IoT technology.

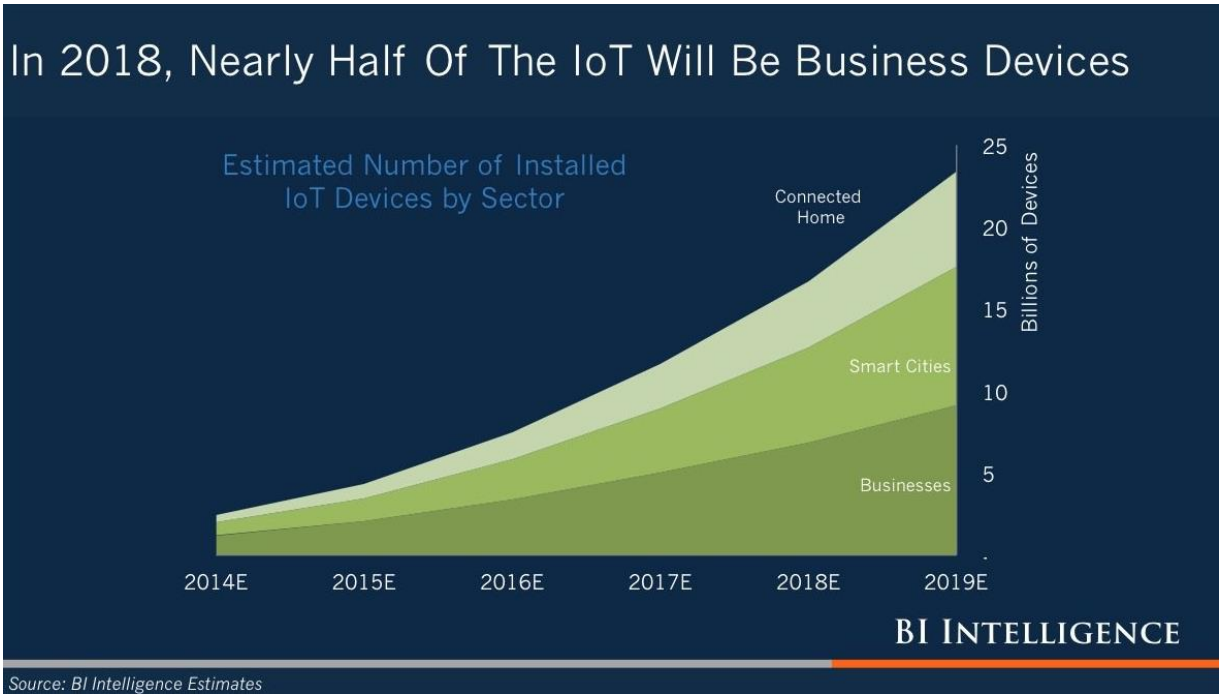

Figure 1.2.1: Estimated Number of Installed IoT Devices by Sector

Based on the data from Figure 1.2.1, we can see from 2014 to 2019, there is a significant increase of IoT devices used by the following sector. Being successful in the digital age doesn't just require knowing the latest buzzwords; it means identifying the transformational trends (Shelagh D, 2018). As we are closely entering the year 2020, every business organization have to keep up with the technology trend which is currently now Internet-of-Things. If one organization can fully master the extend and functionality of the IoT technology, it maybe a key driver in their respective sector market segment. Currently, IoT can be divided to consumer IoT, business IoT and government IoT. Business will be the top adopter of the IoT technology, as we can clearly see in the production of newly IoT implement products. The following adopter will be government then the consumer. Why consumer is the last adopter in IoT is because some consumer might not have a properly understanding of the impact of IoT in their life.

1.2.2 Machine Learning

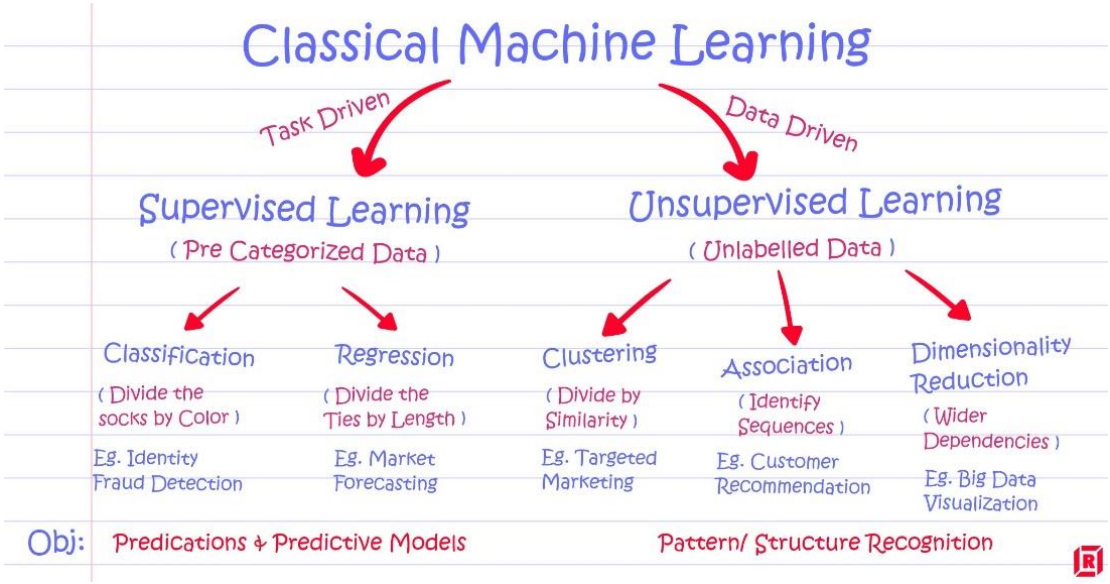

Figure 1.2.2: Types of Machine Learning

What is Machine Learning? Machine-learning algorithms are responsible for the vast majority of the artificial intelligence advancements and applications (Karen H, 2018). Nvidia states that "Machine Learning at its most basic is the practice of using algorithms to pass data, learn from it, and then make a prediction about something in the world." Machine learning can be categorize into 2 main categories namely supervise learning and unsupervised learning. Supervised learning is making predictions using data like example predicting an incoming email either it is spam or not spam. At the end, there is always an outcome that we are trying to predict. In unsupervised learning, it is like extracting structure from data. Example of a situation would be how we want to segment a clustered of shoppers in a supermarket into clusters that have the same similar behaviors/characteristics. At the end, there is no right answer.

So how does machine learning work? First, we train a machine learning model using labeled data (data that has been labeled with the outcome). The main important aspect of machine learning is to have a very good labeled data. Most of the time, this is the part which consumes the most time and resources as it needs to collect all the data. After we

have all the labeled data, now the machine learning model learns the relationship between the attribute of the data and its outcome.

1.2.3 Smart Pillow

Smart pillow is just like an ordinary pillow that is “smart”. What does smart mean in a pillow? The smart pillow has build in electronics and the outside just looks like any normal consumer market pillow. The reason why there is build in electronics is because all these are sensor for sleep monitoring. There are also tons of function that vary from different types of smart pillow. Sleep monitoring is the most basic function. Some of them have anti-snoring function which can help the user to stop snoring. Smart pillow can detect your snoring and alert you to reposition your sleeping posture as snoring is cause by block airways. Hence electronics such as speaker and vibrating motor are integrated into the pillow to alert the user. There also some smart pillow that helps the user have a better sleep experience through music. Smart pillow with integrated speaker and latest Bluetooth technology can allow the user to listen to peaceful music in order to sleep.

1.2.4 Motivation

The main motivation for this project is to create a product that can allows the user to control their sleep duration through a sleep monitoring system. Other aspect that also increases the motivation to create this product is that currently now in the consumer market, the sleep monitoring device is still consider a new technology and not many products are listed in the market. Even if they are listed, the price of it will be very expensive. Hence this gives motivation to develop a sleep monitoring device using affordable components.

1.3 Objectives

The objective of this project is to provide a sensor-based measurement of the sleep data of the user. This is hoped to provide the user with a better quality of sleep. All process can be done effortlessly due the implementation of IoT technology.

Another aim of this project is to implement machine learning technique into the product system. Utilizing the machine learning technique, the product is able to classify the sleep data into sleep rating which user can learned about their sleeping behaviors.

As for the sub objective of the project includes

- The product has to be as portable as possible. This ensure that the product can be taken anywhere especially during travel.
- The product must also have a visual presentation of the data. Basically, meaning a GUI interface has to be implemented into the product system.

1.4 Proposed approach/study

The proposed approach use in this FYP is starting with understanding what is a smart pillow and finding ways how can smart pillow helps in sleep monitoring. After that would be understanding IoT as it will be apply into the smart pillow for it to collect data. After understanding how sleep data is being collected, next would be how to utilize the sleep data which is using machine learning. Before beginning the machine learning, finding which data to include into the dataset comes first then only understanding which machine learning type to use and model.

1.5 Highlight of achievement

Highlights of all the achievement that has been achieved:

- Successfully build a smart pillow with IoT capability.
- The smart pillow is able to collect sleep data of the user.
- All sensors can detect and sends data to Arduino Uno.
- Arduino Uno can send data to Raspberry Pi.
- Raspberry Pi is able to run machine learning script on the dataset.
- A machine learning model that can predict the sleep rating of the user.
- Sleep rating and other sleep data can be view by user on an IoT platform.

1.6 Report Organization

The FYP report organization is as follows:

- Chapter 1: Some introduction of IoT, machine learning and what is a smart pillow. Then there is the what gives motivation for this project and the objective that this project is trying to achieve.
- Chapter 2: A few of the related works in the field of sleep monitoring. Here, smart pillow is compared to 3 related works and states the pros and weakness of these related works.
- Chapter 3: Give the overview of the whole system in terms of its hardware and software implementation. It also gives the guideline to user on how to operate the smart pillow.
- Chapter 4: Discuss the methodology that is use to approach this project. The requirements and some info of the requirements to build the smart pillow is also stated here.
- Chapter 5: Give the test case on how to test the smart pillow. How the sleep rating is classify by the smart pillow is also written in detailed here.
- Chapter 6: Final conclusion and project review of this whole FYP project.

Chapter 2: Literature Review

2.1 A Dense Pressure Sensitive Bedsheet Design for Unobtrusive Sleep Posture Monitoring

The aim of thus research is to create a specialized bedsheet is to record the pressure distribution of the body while sleeping and then perform data analysis for medical applications. (Jason J. Liu, et al., 2013)

2.1.1 The Design of Dense Pressure Sensitive Bedsheet

For this existing research, the dense pressure sensitive bedsheet design is aim to record the pressure distribution of the body of patient while sleeping and then preform data analysis for medical applications. This application also includes the use of IoT related technology in it. The dense pressure sensitive bedsheet design is basically aim for patient that recently had a surgery around any part of the body such as around the hip or back area. Due to having a recent surgery, the particular patient, can not sleep on a fix sleeping posture for a long time. This is where the dense pressure sensitive bedsheet design will detect a limited pressure be applied on the area of the patient sleeping and send alert signal to the patient or caregivers. By, this the patient or caregiver can change the sleeping posture. The design consists of 3 parts, basically the bedsheet which is the pressure and sensor array, a data sampling unit (IoT circuit) and a tablet for data analysis and storage. The sensor array is based on eTextile material which is a fiber-based yarn coated with piezoelectric polymer. The initial resistance between the top and bottom surfaces is high. When extra force is applied on the surface of the eTextile, the intra-fibers will be squeezed together and the electrical resistance will become smaller.

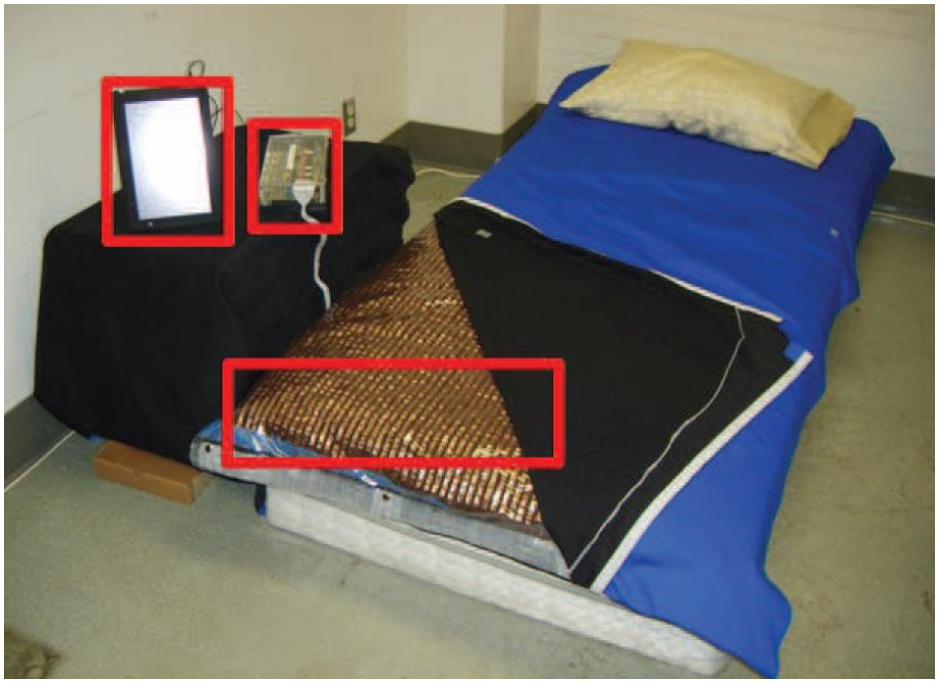

Figure 2.1.1: The design of dense pressure sensitive bedsheet

2.1.2 Strong Points of the product

One of the main selling point of this design is it can produce a high-resolution reading. The bedsheet can offer high-resolution sensing. Given enough resolution, it can possible to qualify the applied pressure on body parts and enable high accuracy medical diagnosis. The sensors are sensitive enough to capture the whole body pressure.

2.1.3 Comparison with proposed solution

Even though, this dense pressure sensitive bedsheet design has a high-resolution reading, the downside is the portability. Being a bedsheet, it means the size is very large and will be a hassle if a user wants to move from one room to another. Travelling with it will also be an issue. Unlike the proposed solution, which uses pillow instead of a bedsheet makes portability way better. Moving and travelling with will not be even an issue, as a pillow can be carry even by a child and stuff into a luggage bag when travelling. Since the dense pressure sensitive bedsheet design used a bedsheet, the bedsheet it used is actually only applicable for single size bed. Hence, universalizability becomes an issue for this

bedsheet design. Compare to the proposed solution, a pillow is universal as it can be use on a size of bed, being a single, queen or king size bed. A pillow can be used by anyone from different ages and size. As for the bedsheet design, for a tall person or big size person, sleeping on it may be an issue.

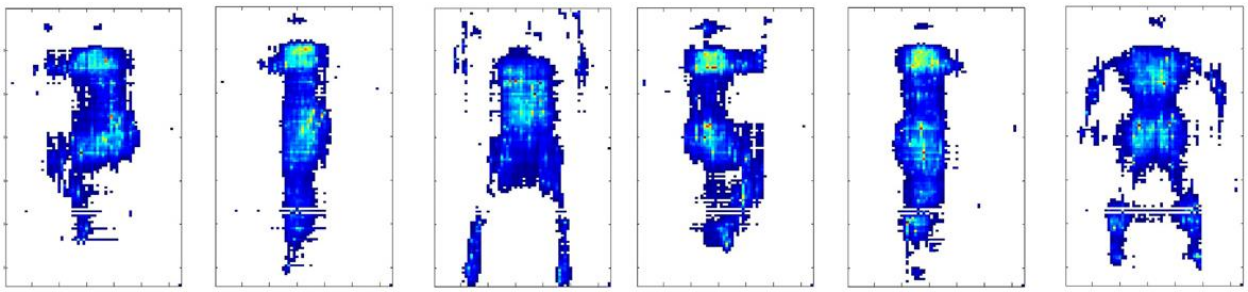

Figure 2.1.2: The pressure image capture by the sensors

2.1.4 Advantages and Disadvantages of Design

Advantages	Disadvantages
• High sensitivity Has high sensitivity sensors which can accurately capture the pressure point of the user.	• Portability Carrying the product especially during travel will be a hassle. • Universalizability Not all bed size can be use with the product. Product only applicable to single size bed.

Table 2.1.1: Advantages and disadvantages of dense pressure sensitive bedsheet design

2.2 Sleep Monitoring System Using Microsoft Kinect v2 Sensor

The aim of this research is to introduce the Kinect sensor based simple sleep monitoring system to gather the sleep movement, posture, and environment not only to collect sleep movement information but also to extract the overall sleep information

(Jaehoon Lee, et al., 2015). The system design does not require the user to wear any troublesome sensing device, thus the proposed system is more natural and comfort.

2.2.1 The design of Sleep Monitoring System Using Microsoft Kinect v2 Sensor

The design of Sleep Monitoring System Using Microsoft Kinect v2 Sensor is basically using the video based approach to monitor sleep activity. In order to monitor the sleep state with video, it is necessary to firstly recognize the shape of the human body and the image processing based approach is essential to extract the human body from the input images. This can be done, because camera now can obtain color, infrared and depth information. This sleep monitoring design used the Microsoft Kinect v2. This version of design specifically chooses the Microsoft Kinect v2 as it is the latest version of Kinect and this version of Kinect provides the position of 25 joints, and detection range has been more improved compared to the previous version Microsoft Kinect v1. The Microsoft Kinect v2 is equipped with TOF (Time of Flight) which is configured with one pair of receptors to achieve a more accurate depth information than the Kinect v1. Other than a Microsoft Kinect v2, a computer running Microsoft Windows OS and Visual Studio having OpenCV library is also need for the whole system to run. Another component addition into the system is the TI (Texas Instruments) sensor tag. This sensor is responsible for obtaining the temperature and humidity of sleep environments. This sensor is connected with sleep monitoring application by Bluetooth, and this sensor provides 6 main pieces of data such as temperature, humidity, pressure, accelerometer, gyroscope, and magnetometer.

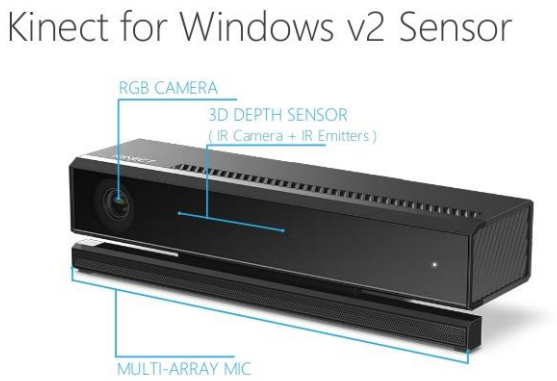

Figure 2.2.1: A Microsoft Kinect v2 having a RGB camera, 3D Depth Sensor (IR Camera and IR Emitters), Multi-Array MIC

Figure 2.2.2: Basic setup of the Sleep Monitoring System Using Microsoft Kinect v2 Sensor

2.2.2 Strong points of the product

Unlike other sleep monitoring design, this design is unique in its own form because it used image processing technique. The direct sensor attachment based method can be unacceptable by some people. Having to wear multiple wires and sensing devices can lead to uncomfortable sleep environments and this may negatively affect the measurement of sleep state. Since this design only used the Microsoft Kinect v2, the user will not even need to have any contact with the device. The user just need to make sure the Microsoft Kinect v2 is properly capturing the whole body of the user. Another strong selling point is this design is it can achieve an accurate depth information even in very dark conditions which is the most important aspect as mostly user will sleep in a dark room.

2.2.3 Comparison with proposed solution

One of the downside of the Microsoft Kinect v2 Sensor is that privacy can be an issue. The Microsoft Kinect v2 can also be consider as a surveillance device. The Microsoft Kinect v2 Sensor not only can capture image, it also can capture audio which more makes privacy an important issue. Some user might be concern with the data or image capture by the Microsoft Kinect v2 being stolen. Unlike the proposed solution which does need any video recognition, privacy of the user will not be a big issue. In terms of cost, the proposed solution is basically more cheaper compare to the Microsoft Kinect v2. Since the Microsoft Kinect v2, need a computer to do the processing, it adds more cost for the user unlike the proposed solution which uses a cheap microprocessor.

2.2.4 Advantages and Disadvantages of Design

Advantages	Disadvantages
• No physical contact of product with user User will not need to feel uneasy unlike outer product which has a lot of wires connected to the user. • Works in dark condition The product is able to capture clear image of user even in very dark condition.	• Security Data captured can be easily compromise due to the weak security of the system.

Table 2.2.1: Advantages and disadvantages of sleep monitoring system using Microsoft Kinect v2 sensor

2.3 A Non-invasive Wearable Neck-cuff System for Real-time Sleep Monitoring

The aim of this research is to developed a non-invasive platform for monitoring vital signs throughout sleep. Method use is a multi-signal technique for monitoring sleep

in which a set of physiological sensors are incorporated inside a soft neck-cuff and are recorded continuously. (Mahsan Rofouei, et al., 2011).

2.3.1 The Design of Non-invasive Wearable Neck-cuff System for Real-time Sleep Monitoring

The design of the Non-invasive Wearable Neck-cuff System applies IoT technology in its design. All the sensing and processing components is all being tuck into the neck-cuff. Only the neck-cuff is having physical contact with human skin. All the data for analysis will be sent into either a cell phone or a computer. From there further data transfer to cloud server can also be done. What important electronic components can be seen in the neck-cuff is a low-power MSP430 microcontroller, a Bluetooth radio module, and a rechargeable LiPol battery with a capacity of 100mAh. The two sensing electronic components inside the neck-cuff is a stethoscope and an oximeter. The function of the oximeter is to monitor the oxygen saturation level of the blood. It is usually placed or attached to a thin part of the body, a fingertip or earlobe. The stethoscope function is to record the breathing sound which the neck-cuff is attached to the neck. As for the processing part, to continuously provide a connection between the microprocessor and computer, a 2.4Ghz Ring Antenna has to be integrated to the neck-cuff. This is to create a strong connection throughout any sleeping event.

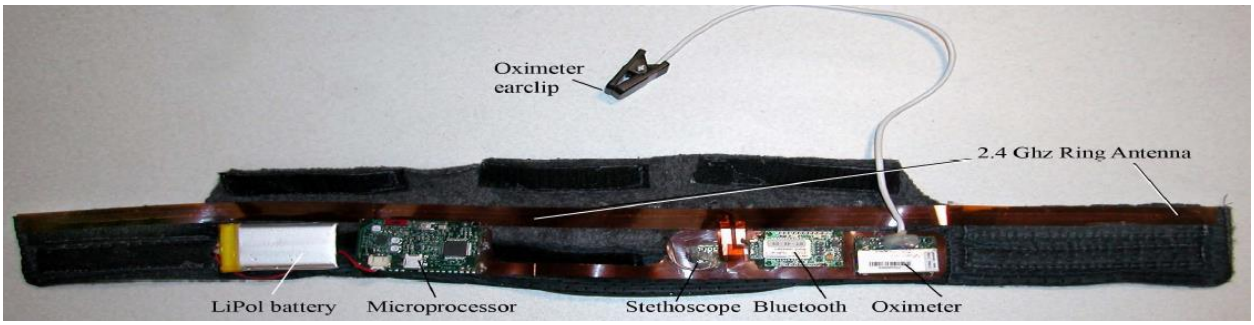

Figure 2.3.1: Components inside the non-invasive wearable neck-cuff

2.3.2 Strong points of the product

What makes this product shine is the portability of the neck-cuff. The neck-cuff can be worn anywhere without many wires dangling out except for just the oximeter clip wire. Another reason why the neck-cuff is portable is because it used the integrated LiPol battery as a power source. A LiPol battery is much better compare to standard commercial battery as there are not rechargeable. Having a LiPol battery capacity of 100mAh means the neck-cuff can be worn for a few days without needing to charge. Since the neck-cuff design uses a low-power microprocessor, the battery life-span can be extended.

2.3.3 Comparison with proposed solution

One of the weakness or downside of the non-invasive wearable neck-cuff design is comfortability. Some user might find it irritating to continuous wearing a neck-cuff especially during sleeping. Being uncomfortable when sleeping can further lead to sleeping disorder problems. Unlike the proposed solution, a pillow will not interfere with the user's sleep. Another weakness of the non-invasive wearable neck-cuff design is it uses Bluetooth as connection between the neck-cuff and computer. Unlike the proposed solution which uses the WiFi module on the Raspberry Pi 3 b+, having a WiFi connection with 5GHz is much better than a Bluetooth than only can support up to 2.4GHz. 5GHz connection can provide a faster data transfer and data loss due to interference from other wireless devices.

2.3.4 Advantages and Disadvantages of Design

Advantages	Disadvantages
• Portability User can wear the product anywhere. The product is power by a rechargeable battery which makes it portable.	• Uncomfortable at neck section Some user might feel uncomfortable at the neck section due to having the product always on. • Slow data transfer

	Data transfer to other appliances might be slow due to product using Bluetooth.

Table 2.3.1: Advantages and disadvantages of non-invasive wearable neck-cuff system

Chapter 3: System Design

3.1 Overall System Design

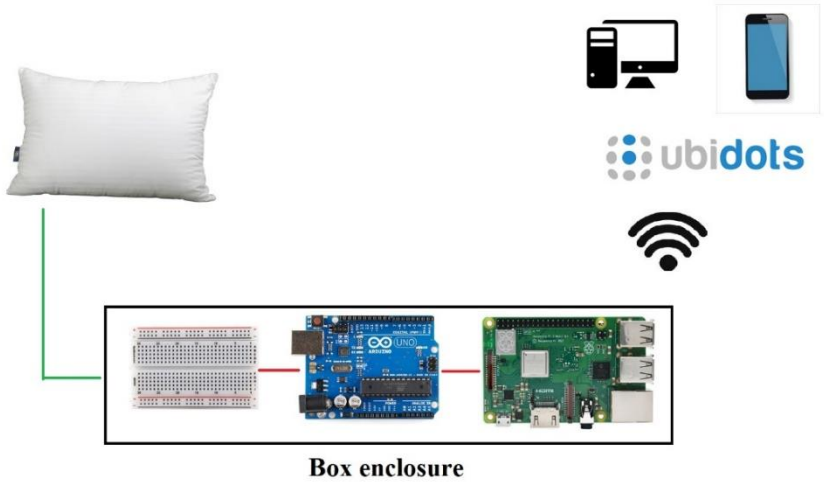

Figure 3.1.1: Overall system design of smart pillow.

The overall system design of the FYP project is just like the figure above. All wiring and component (DHT22, resistors) are all connected onto the breadboard. The only components not placed on the breadboard is the three force sensitive resistor which will be taped onto the surface of the pillow. All the sensor components will be connected to the Arduino Uno through the breadboard. From the Arduino Uno a single MicroUSB cable will be connected to the Raspberry Pi. This connection is a UART connection which the data is being sent and it also powers up the Arduino Uno. In the system, Raspberry Pi is responsible for the computing. All the data obtained from computing will then be sent to cloud data storing service which this system use is called Ubidots. Hence at the end, Ubidots functions as a user interface for user to interact will all the data obtained from the system such as user's time of sleep, total sleep, amount of toss and much more data.

3.2 Flow Chart of System

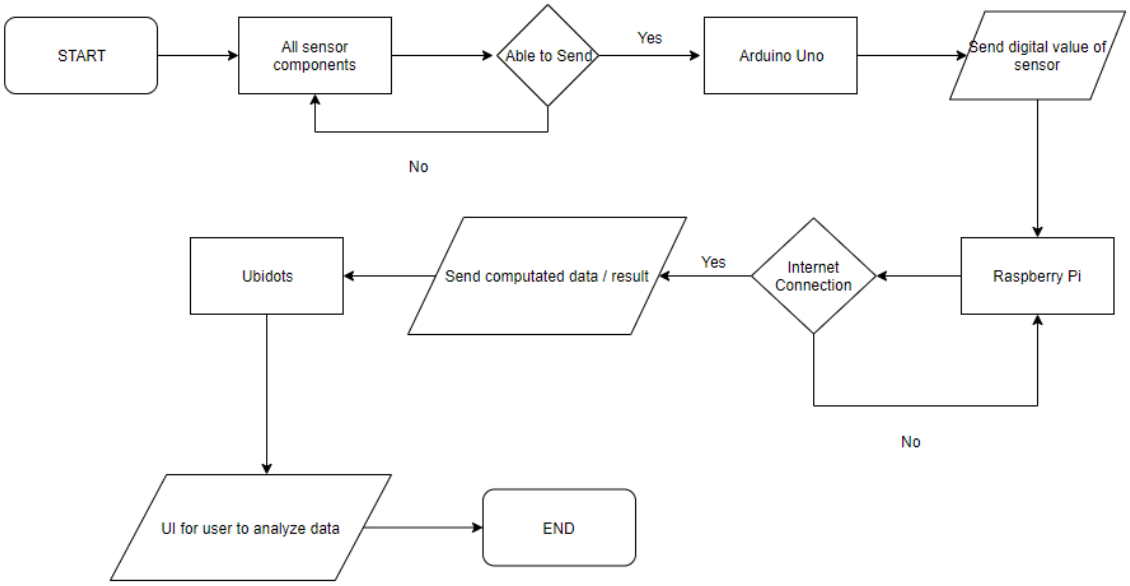

Figure 3.2.1: Flowchart on how data collect, process and display to user.

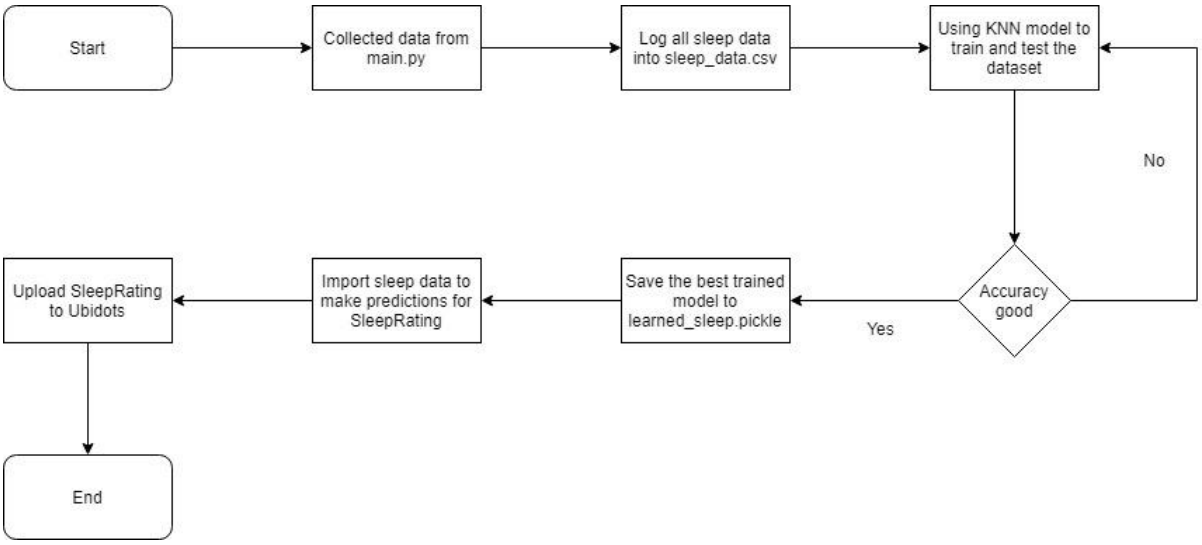

Figure 3.2.2: Flowchart on creating the best trained machine learning model.

3.3 Hardware Implementation

The hardware consists of 3 main parts. The breadboard with all the sensors, Arduino Uno and Raspberry Pi. The connection will be from sensors to breadboard to Arduino to lastly Raspberry Pi. As for power of the whole system, only one connection wire is needed which is a single MicroUSB cable connected to the Raspberry Pi.

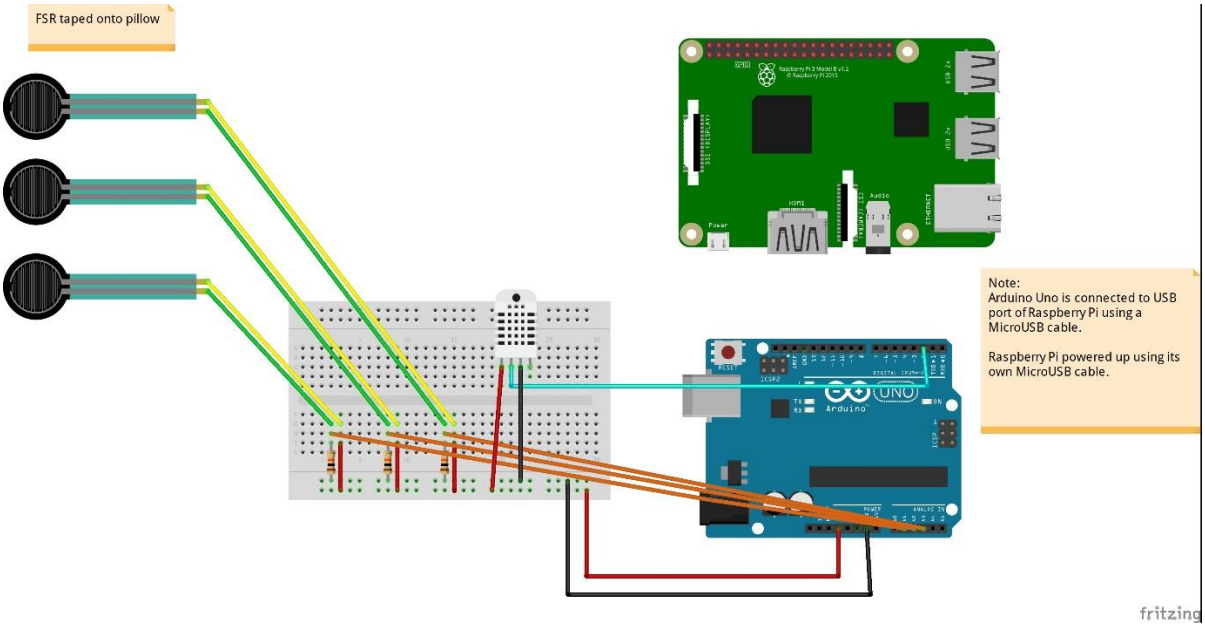

Figure 3.3.1: Hardware plan of smart pillow.

The hardware implementation of the whole project is as follow the Figure 3.3.1. Three of the FSR are located on the pillow surface are secure with tape. Since there is a distance between the FSR and the box containing all the component (breadboard, development board), extension wire has to be soldered onto the FSR pins. Here single core copper wire is soldered and connected to the breadboard inside the box. A single cable for power supply is only needed to exit the box to supply the Raspberry Pi which power of around 5V. A MicroUSB will be needed to connect the Arduino Uno to Raspberry Pi. This enables data to be sent to Raspberry Pi and also supply power to the Arduino Uno.

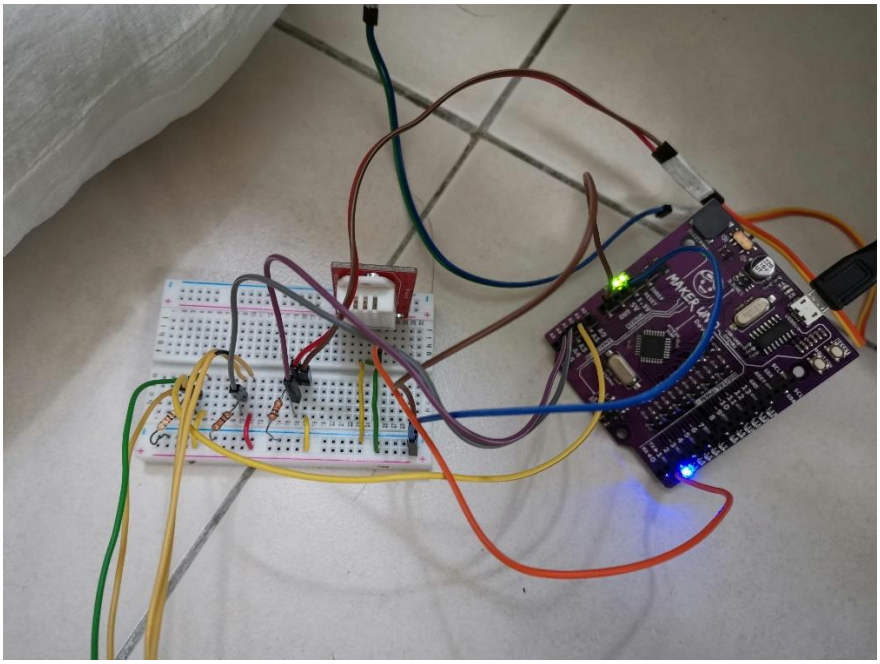

Figure 3.3.2: Sensors connected to breadboard then connected to Arduino.

Figure 3.3.3: Breadboard, Arduino, Raspberry Pi stored in the enclosure box.

Figure 3.3.4: Position where 3 FSR should be taped.

3.4 Software Implementation

The first script of the project is the Arduino script named “sensors.ino”. The list of the data which is collected from this script are as Table 3.4.1. All the data will be sent to Raspberry Pi thorough UART connection with an interval of 5s.

fsr1	The middle FSR
fsr2	The left FSR
fsr3	The right FSR
temp	Temperature from DHT22
humi	Humidity from DHT22

Table 3.4.1: All sensor data collected by the Arduino Uno.

The second script is a python script named “main.py” which is stored in the Raspberry Pi. This python script contains most of the function such as for receiving the data from Arduino, processing the data, uploading required data to Ubidots and exporting data to CSV. The whole recording process will only start when the user pressed on the “Sleep/Awake Button” in Ubidots. After the button is pressed, all data will be log into the Raspberry Pi every 5 minutes. The recording process will stop when the user pressed on the “Sleep/Awake Button” again. At this point, all data will be uploaded to Ubidots and the machine learning script “sleep_ml.py” will run. At the end of the script, the output will be display to Ubidots and the CSV file called “yesterday_night.csv”. This CSV file function as to keep all the data of user’s yesterday night sleep.

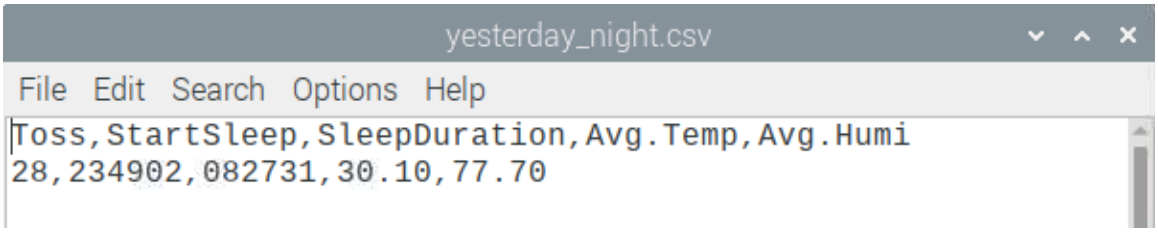

Figure 3.4.1: CSV file to log user yesterday’s night sleep.

The third script is also a python script named “sleep_ml.py” which is stored in the Raspberry Pi. This script contains all the function for machine learning. Here the script runs the machine learning using the scikit-learn library and tensorflow. The machine learning algorithm that is used is the KNN model which stands for K-Nearest Neighbors. KNN is mainly used for classifying data into certain catagories which is what this project wants to achieved – classifying the sleep rating of user. To start the machine learning process, a dataset has to be obtained first. This is where the second script come into work as it collects all the required data of user’s yesterday night sleep. All the data is stored into the dataset name “sleep_data.csv”.

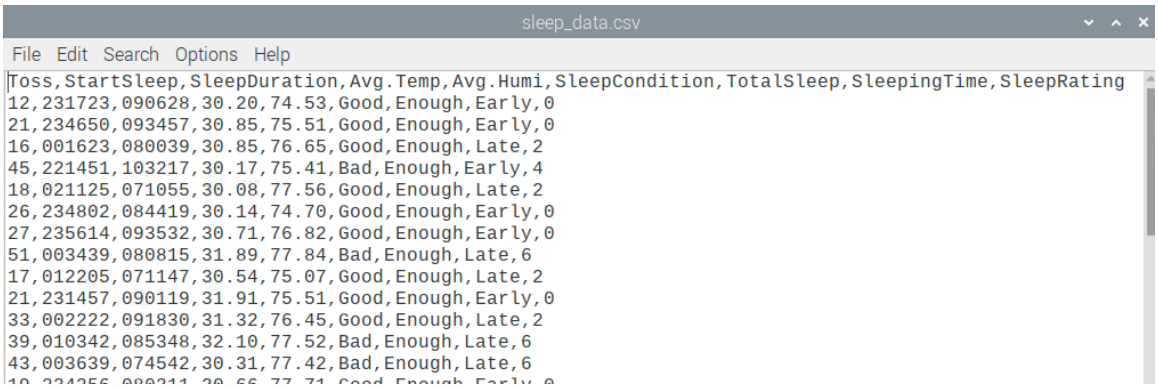

Figure 3.4.2: CSV file to log all the sleep data.

Once the dataset is completed, the data can then be loaded in. The data will be split into training data and testing data using the KNN model. What we want to achieve is to obtained the best accuracy after several train test and the best model will be save into “learned_sleep.pickle” using the pickle library. Using the most accurate saved model, the “sleep_ml.py” can finally predict the sleep rating of user and upload the rating to Ubidots.

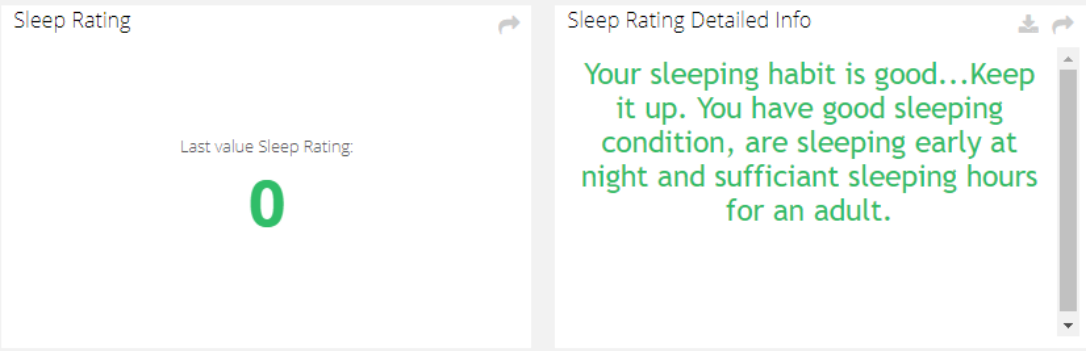

Figure 3.4.3: The sleep rating of user in Ubidots.

3.5 Guideline on how to operate the smart pillow

Before even starting to use the smart pillow, the user must ensure all the coding script on both the Arduino Uno and Raspberry Pi is the latest one. The Arduino Uno script "sensors.ino" have to be pre-loaded into the Arduino. Then Raspberry Pi has to have an internet connection first and must be connected to a power supply, recommended a 5V power outlet. After everything is power up, now the user can use either a phone or computer to access the interaction part of the system on Ubidots.

To start the monitoring or when user wants to start sleeping. User have to press the button in Ubidots and it will show "Sleep" mode as in Figure 3.5.1. When user wants to end the monitoring, user simply just have to press the button again and it will revert back to "Awake" mode as in Figure 3.5.2.

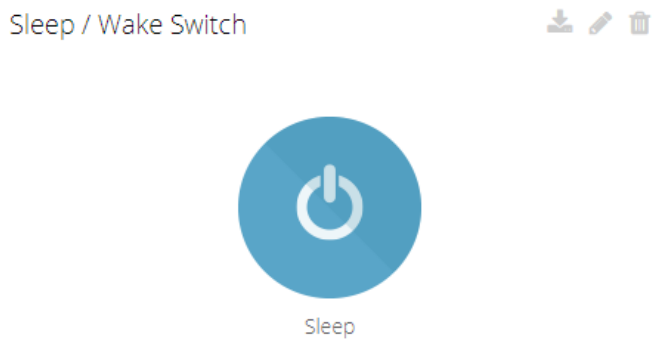

Figure 3.5.1: Button shows “Sleep” mode to indicated monitoring has started.

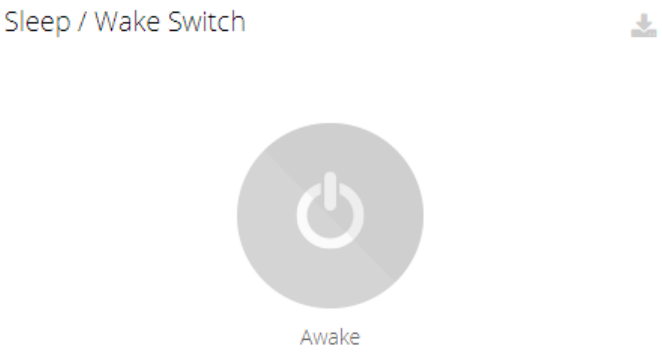

Figure 3.5.2: Button shows “Awake” mode to indicated monitoring has ended.

Chapter 4: Methodology and Tools

4.1 Design Methodology

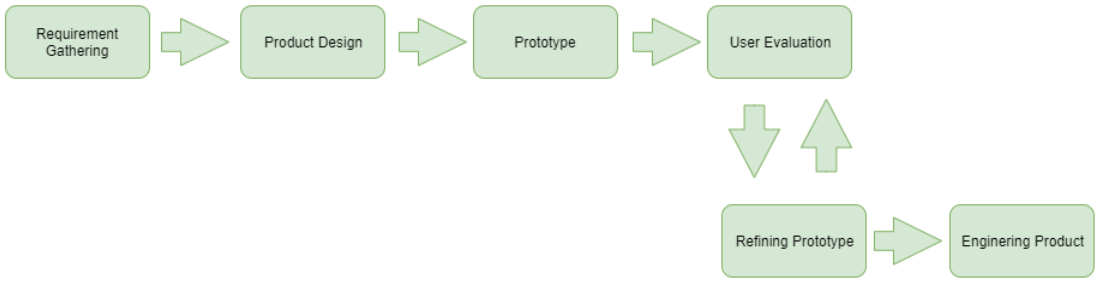

Figure 4.1.1: Process of prototyping model

The methodology that this project uses to achieve the output is the prototyping model. The Prototyping Model is a systems development method (SDM) in which a prototype (an early approximation of a final system or product) is built, tested, and then reworked as necessary until an acceptable prototype is finally achieved from which the complete system or product can now be developed (Margaret R, 2005). This model works best for this project as not all the project requirements are known at the start of the project. The prototyping model has several steps in it which needs to follow in order. The first phase of the prototyping model indicates that the new product requirements are defined as much as possible. This means the project requirements such as which electronics component, microcontroller and software needed are listed down first. Then the preliminary design such as the layout of the electronic components as well as wire connections to the microcontroller are created. Then the first prototype of the new system which includes the hardware part and software part has to be constructed. If there is any additional function or component added, the second prototype is where it has to be shown. If the second prototype is acceptable and no refining that has to be done, the final system or the engineering sample will be develop.

4.2 System Requirement

Here is the list of components and software which were being used in the project.

Sensor/Components	
Breadboard	1 X DHT22
Jumper Wires	3 X 10k Ohm Resistors
Single Core Copper Wire	3 X Force Sensitive Resistors
Development Board	
Arduino Uno	Raspberry Pi 3B+
Software	
Arduino IDE	PyCharm (Python programming)
Geany (Python programming)	
Website	
Ubidots	https://app.ubidots.com/ubi/insights/
Programming & IT Skills	
Raspbian Operating System	Know some basic linux based programming on operating the Raspberry Pi operating system.
C/C++	The programming language used in Arduino IDE.
Python Programming	The programming language used to code the main.py.
Machine Learning (scikit-learn)	Know how machine learning works with python.
Soldering Components	Some soldering skills when soldering the FSR connectors to single core copper wires.

Table 4.2.1: All requirements of smart pillow

4.2.1 Sensors/Components

- Force Sensitive Resistor (FSR)

Figure 4.2.1: Force Sensitive Resistor

The purpose of the FSR in the project is to detect the number of toss the user makes during his sleep period. The FSR is a sensors that allow the user to detect physical pressure by squeezing and weight. FSR can be consider a resistor as it changes it resistive value based on the amount force (N) apply on it. As for the accuracy of it, it is not very accurate as it needs some calibration. When connecting the FSR, a resistor (in the project a 10k Ohm) is used along side the FSR as a pull down resistor.

- DHT22

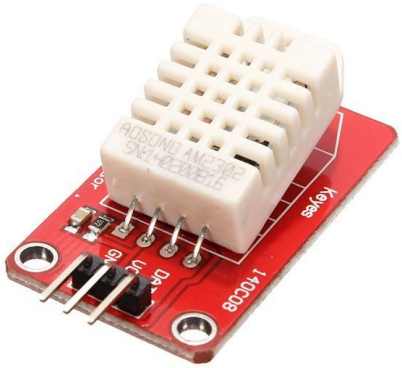

Figure 4.2.2: DHT22

The DHT22 is the sensor that detects the temperature and humidity. Here in this project DHT22 is selected over DHT11 as it provides a more accurate and a slightly larger range. Using it is relatively simple as the coding and connection is quite straight forward.

4.2.2 Development Board

- Arduino Uno

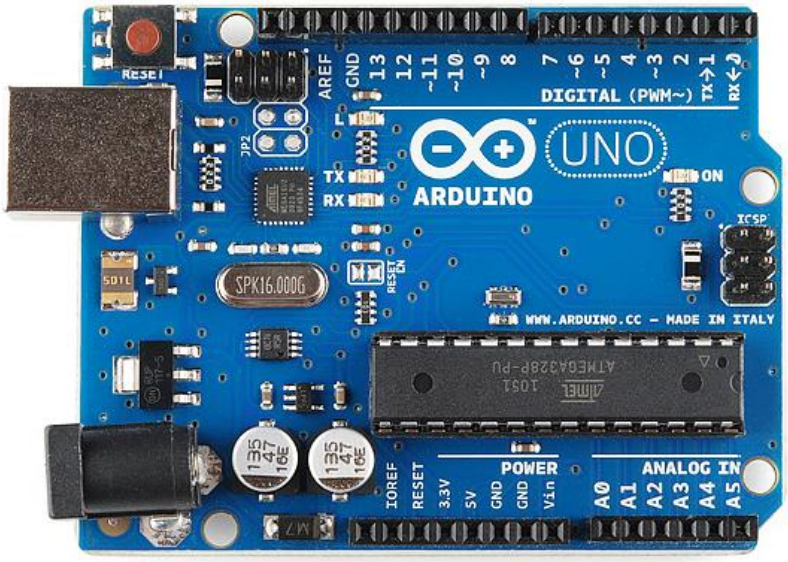

Figure 4.2.3: Arduino Uno Board

Figure 4.2.4: Similarity of Arduino Uno to Maker Uno

The Arduino Uno is chosen because it is easily to use in terms of receiving data from the sensors. Here the Arduino Uno have 6 analog pins (A0 til A5), where the

3 FSR is being connected. Compare to Raspberry Pi, Arduino Uno has analog pin while Raspberry Pi does not. Arduino Uno also have digital pins and digital pins with PWM. In this project, a relatively similar board to the Arduino Uno is being used called the Maker Uno. All functions and pinout are totally the same so any of these 2 boards can be use.

- Raspberry Pi 3B+

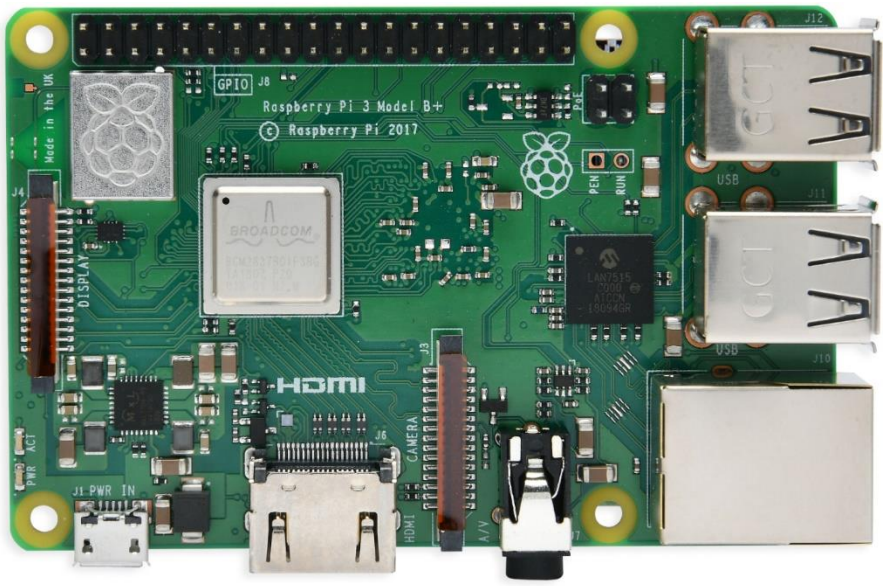

Figure 4.2.5: Raspberry Pi 3B+ Board

Raspberry Pi is more complex and have more functionality compare to the Arduino Uno. The Raspberry Pi used in this project is the 3B+ which has WIFI build in as internet connection is very vital in this project. Another reason why Raspberry Pi is chosen is because it is capable of doing some machine learning functions. Tensorflow can be install onto the Raspberry Pi which is an end-to-end open source platform for machine learning. Even though this model of Raspberry Pi has limited processing power, it still is capable of running the trained machine learning model.

4.2.3 IoT Platform

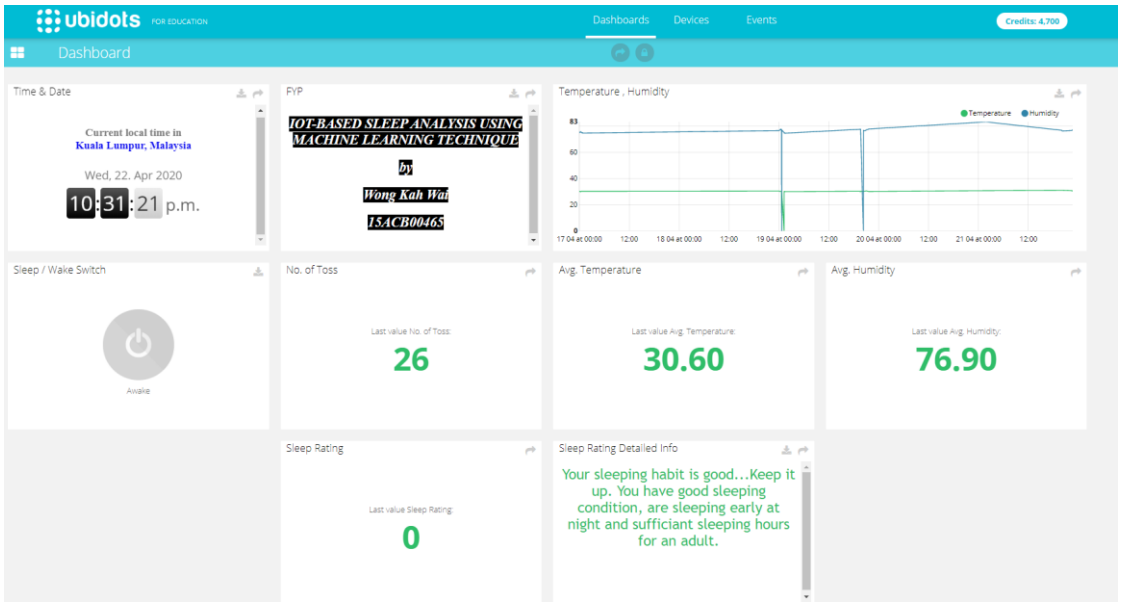

Figure 4.2.6: Dashboard of Ubidots

Ubidots is the IoT platform used as the interactive UI for the user. The Ubidots used is the Education version so some functionality is limited. Here the user will be able to control and view data. Data is sent from Raspberry Pi through the Ubidots API. Some website programming will also be needed when writing the SleepRating using the HTML canvas function in Ubidots.

Chapter 5: Implementation and Testing

5.1 Final product

Here is how the smart pillow will look like with a pillow cover. The blue box is the enclosure box and it will be place slightly above the smart pillow on the bed.

Figure 5.1.1: Final product of smart pillow

5.2 Test Cases

5.2.1 Test Case 1: Arduino Receiving Sensor Data

Here Arduino is tested to see if all the sensors data is constantly being read by the Arduino.

To Test: The serial monitor of Arduino IDE can be opened to check the data.

Result: Serial Monitor of Arduino IDE showing the sensors reading.

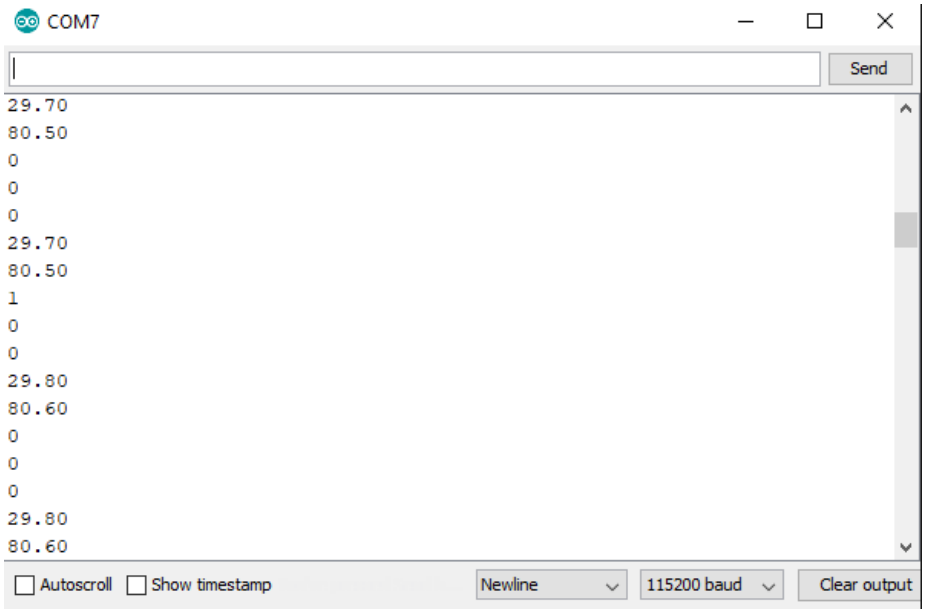

Figure 5.2.1: Arduino Serial Monitor.

5.2.2 Test Case 2: Ubidots Button Start/End Sleep Recording

Ubidots button tested to see if the recording will start and end if pressed.

To Test: Button is pressed to change to “sleep” mode and pressed again to change to “awake” mode.

Result: Button is working and can start the recording process as in Figure 3.5.1 and Figure 3.5.2.

5.2.3 Test Case 3: User's Yesterday Night Sleep Recorded

See if the user's yesterday night sleep data is recorded in the CSV file.

To Test: Check the folder of the script if a yesterday_night.csv file is created and the data should be the same as Ubidots dashboard data.

Result: A CSV file containing user's yesterday night sleep data as in Figure 3.4.1.

5.2.4 Test Case 4: Sleep Rating Displayed to User

Check if the correct sleep rating number along with the correct sleep rating information is display in Ubidots.

To Test: Check the sleep rating number is align with its sleep rating information. Refer to Table 5.3.1 to check.

Result: A proper sleep rating number along its sleep rating information is display in Ubidots as in Figure 3.4.3.

5.3 Sleep Quality Classification Using Machine Learning

The machine learning used in this project is a supervised machine learning meaning we train the machine using data which is well labeled. This means some of the data is already tagged with the correct answer. Then supervised learning algorithm learns from the labelled training data and predicts the outcome which is the sleep rating. The first CSV (yesterday_night.csv) only stores the user's yesterday night sleep data which is no. of toss, start sleeping time, total sleep duration, avg. temperature and avg. humidity. Here the avg. temperature and avg. humidity will not be used in the dataset as most of the data does not vary much. Meaning there is no a record of a very hot room or very cold room to help us in classifying the data.

Then we have the second CSV (sleep_data.csv) which is the dataset that we are going to load into our machine learning. In this dataset, it has the following features or label: Toss, StartSleep, SleepDuration, Avg.Temp, Avg.Humi, SleepCondition, TotalSleep, SleepingTime, SleepRating. Because this is a supervised machine learning, we have to tagged the following features with the correct answer. They are:

- SleepCondition
    - This is how is the condition of user when sleeping either he is having a peaceful or stressful sleep experience. This is based on the number of toss the user makes per night. According to Wall Street Journal, the average adult change their position between 3 to 36 times a night (Sumathi R, 2013).
    - We label the number of toss <= 36 as "Good" and > 36 as "Bad".

- TotalSleep
    - This is the duration of sleep of user per night. Most healthy adults need between 7 – 9 hours of sleep per night in order for them to function the best the next day (Melinda S. et al., 2019).
    - We label the TotalSleep >= 7 hours as "Enough" and < 7 hours as "Lack"

- SleepingTime

- This is the time which user start sleeping.
- We label the sleeping time < 12:00 AM as “Early” and > 12:00 AM hours as “Late”.

- SleepRating
  - This label is the most important as we will also be predicting it using the trained model.
  - The label is labelled as following:

SleepCondition	TotalSleep	SleepingTime	SleepRating
Good	Enough	Early	“0”
Good	Lack	Early	“1”
Good	Enough	Late	“2”
Good	Lack	Late	“3”
Bad	Enough	Early	“4”
Bad	Lack	Early	“5”
Bad	Enough	Late	“6”
Bad	Lack	Late	“7”

Table 5.3.1: Classification of SleepRating

Hence, with this dataset a trained model was able to be produce. Now whenever user logs his yesterday’s night sleep data which is only “Toss”, StartSleep” and “TotalSleep”, he is able to know his sleep rating.

Chapter 6: Conclusion

6.1 Project Review

6.1.1 Strength and Weakness of Smart Pillow

One of the strength of this product is it has IoT and machine learning capability. With its IoT capability, this means the user can control the smart pillow more portable. Since there are tons of IoT platform, the user is not only limited to using Ubidots but if user wish to switch to another IoT platform it is possible with some tweaks with the data sending API. Then there is machine learning which helps user predicts his sleep rating. The machine learning of the smart pillow was able to generate an informative dataset model which in the future this dataset model can be reuse in any other sleep monitoring machine learning related projects.

One of the main weakness of the smart pillow lies in the force sensitive resistor located at the pillow. Since the FSR is always in contact with the head of the user, over some time it can get crush or damage. This is because the FSR is made up of flexible plastic overlay onto flexible printed electrode for contact which mainly is pressed on a hard surface to prevent much more flex to the plastic. The accuracy of the SleepRating predicted by the machine learning model is not also 100% accurate. This is maybe because of the lack of sleep records in the dataset. So sometimes the SleepRating displayed to user might show an incorrect data.

6.1.2 Review

At the end, the project is a success as the output and the objective has been achieved. From the period of the FYP project, lots of knowledge and skills have been applied in order to achieved the desire output. Some of the main knowledge and skills are embedded design, IoT, machine learning and electronics. In terms of programming skills, throughout the study of my degree, the most programming language apply during when coding the project is python and secondly C/C++. There is also some web design (HTML and javascript) used to display the final output in the Ubidots.

Overall if the most challenging part of the project would be the machine learning part as it is the first time for me getting into this field. Since having zero knowledge about machine learning during the start of the project, picking up and learning the basic did take some period of time. Since the core of machine learning here rely on the dataset, gathering and selecting the feature for the dataset also consumed some period of time.

There are also few problems encountered during the whole FYP. One highlightable one would be finding the best way to utilize the FSR. During the process of soldering, one FSR was damage. Direct soldering to FSR is not recommended and FSR should be hook up using a “Amphenol FCI Clincher Connector” but this special connector is not directly available in Malaysia. At the end, this problem was solved through more careful soldering and not leaving the soldering tip too long on the contact pins.

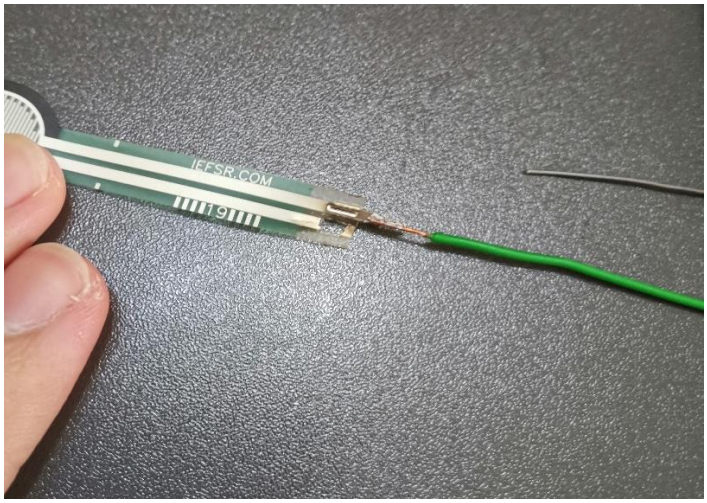

Figure 6.1.1: Damaged FSR contact pin

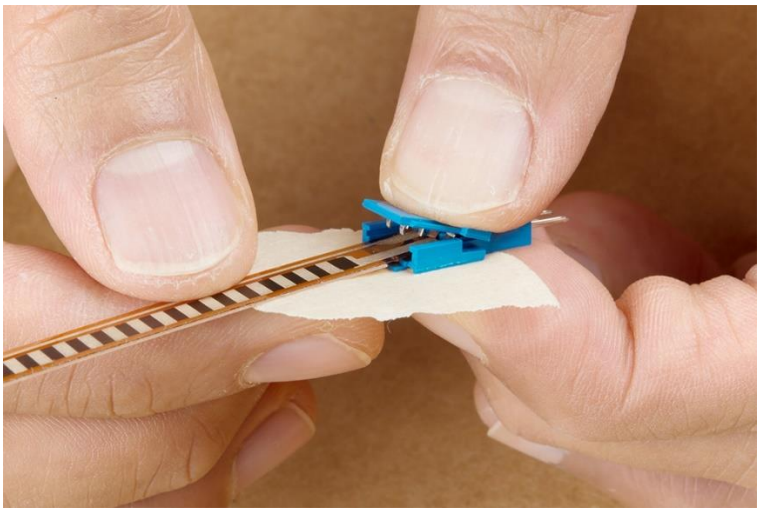

Figure 6.1.2: Recommended way to hook up FSR

In conclusion, the final outcome of the product is able to provide a sensor-based measurement of the sleep data of the user.

6.2 Future Works

One of the future improvement to the product is trying to change the FSR to maybe a more sensitive cloth pressure matrix such as in Figure 5.5.1. This will have a more accurate sensing accuracy compare to the FSR but the downside might be the availability of the product in Malaysia market and the cost.

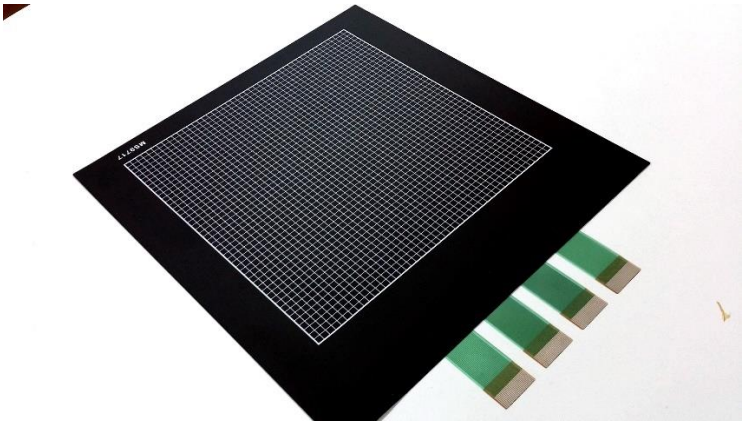

Figure 6.2.1: Cloth Pressure Matrix

The smart pillow also can further enhance its machine learning model in the future. How the machine learning model can be enhanced is by collecting more records for the dataset. Then as more data is collected the model can be continuously trained-tested to obtained a high accuracy reading.

Bibliography

Arduino.cc, computer software 2019. Available from: < https://www.arduino.cc/en/main/software>. [15 August 2019].

J. J. Liu et al., "A dense pressure sensitive bedsheet design for unobtrusive sleep posture monitoring," 2013 IEEE International Conference on Pervasive Computing and Communications (PerCom), San Diego, CA, 2013, pp. 207-215. doi: 10.1109/PerCom.2013.6526734

Karen H. 2018. What is machine learning? Available from: < https://www.technologyreview.com/2018/11/17/103781/what-is-machine-learning-we-drew-you-another-flowchart/>. [20 April 2020]

Lee, J., Hong, M. and Ryu, S. (2015) 'Sleep Monitoring System Using Kinect Sensor', International Journal of Distributed Sensor Networks. doi: 10.1155/2015/875371.

Margaret R. 2015. Prototyping Model Available from: <https://searchcio.techtarget.com/definition/Prototyping-Model>. [2 April 2019].

Melinda S. et al., Why is sleep so important? Available from: < https://www.helpguide.org/articles/sleep/sleep-needs-get-the-sleep-you-need.htm>. [20 April 2020]

M. Rofouei et al., "A Non-invasive Wearable Neck-Cuff System for Real-Time Sleep Monitoring," 2011 International Conference on Body Sensor Networks, Dallas, TX, 2011, pp. 156-161. doi: 10.1109/BSN.2011.38

RaspberryPi.org, computer software 2019. Available from: < https://www.raspberrypi.org/downloads/raspbian/>. [15 August 2019].

Scikit-learn.org, computer software 2019. Available from: <https://scikit-learn.org/stable/install.html>. [15 August 2019]

Shelagh D. 2018. How the Internet of Things will transform consumerism, enterprises, and governments over the next five years. Available from: < https://www.businessinsider.com/7-26-2018-iot-forecast-book-2018-7?IR=T>. [20 April 2020]

Sumathi R. 2013. Find the Perfect Sleep Position. Available from: < https://www.wsj.com/articles/SB10001424127887324595704578241642030220064>. [20 April 2020]

Appendices

Arduino Script: sensors.ino

```
#include <Wire.h>

#include <DHT.h>


//DHT22 Variable

#define DHTPIN 2

#define DHTTYPE DHT22 //DHT22 Model

DHT dht(DHTPIN, DHTTYPE);

float temp;

float humi;


//FSR1 Variable

int fsrPin1 = 1; //Pin A1

int fsrReading1;

int fsrVoltage1;

unsigned long fsrResistance1;  //voltage converted to resistance

unsigned long fsrConductance1;

long fsrForce1;  //Resistance converted to force

bool fsr1;


int fsrPin2 = 2; //Pin A2
```

```
int fsrReading2;

int fsrVoltage2;

unsigned long fsrResistance2;  //voltage converted to resistance

unsigned long fsrConductance2;

long fsrForce2;  //Resistance converted to force

bool fsr2;


int fsrPin3 = 3; //Pin A3

int fsrReading3;

int fsrVoltage3;

unsigned long fsrResistance3;  //voltage converted to resistance

unsigned long fsrConductance3;

long fsrForce3;  //Resistance converted to force

bool fsr3;


void setup()

{

  Serial.begin(115200);

  Wire.begin();

  dht.begin();

}


void loop()
```

```
{
  //Temp & Humi loop
  humi = dht.readHumidity();
  temp = dht.readTemperature();

  //FSR loop
  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);

  //FSR1 data calculation
  if (fsrVoltage1 == 0) {
    //Serial.println("No pressure");
    fsr1 = 0;
  }
  else{
    fsrResistance1 = 5000 - fsrVoltage1;
```

```
    fsrResistance1 *= 10000; // 10K resistor
    fsrResistance1 /= fsrVoltage1;
    fsrConductance1 = 1000000;
    fsrConductance1 /= fsrResistance1;
    //Serial.println("Conductance: ");
    //Serial.println(fsrConductance1);

    if(fsrConductance1 < 6){  //value 6 is calibriated from when FSR is sticked with tape onto pillow
      fsr1 = 0;
    }
    else{
      fsr1 = 1;
    }
  }

  //FSR2 data calculation
  if (fsrVoltage2 == 0) {
    fsr2 = 0;
  }
  else{
    fsrResistance2 = 5000 - fsrVoltage2;
    fsrResistance2 *= 10000; // 10K resistor
```

```
  fsrResistance2 /= fsrVoltage2;
  fsrConductance2 = 1000000;
  fsrConductance2 /= fsrResistance2;

  if(fsrConductance2 < 6){  //value 6 is calibriated from when FSR is sticked with tape onto pillow
    fsr2 = 0;
  }
  else{
    fsr2 = 1;
  }
 }

 //FSR3 data calculation
 if (fsrVoltage3 == 0) {
  fsr3 = 0;
 }
 else{
  fsrResistance3 = 5000 - fsrVoltage3;
  fsrResistance3 *= 10000; // 10K resistor
  fsrResistance3 /= fsrVoltage3;
  fsrConductance3 = 1000000;
  fsrConductance3 /= fsrResistance3;
```

```
   if(fsrConductance3 < 6){  //value 6 is calibriated from when FSR is sticked with tape onto pillow
     fsr3 = 0;
   }
   else{
     fsr3 = 1;
   }
  }

  //Comparing the FSR value to know which side is more pressured
  if(fsr1 == 1 && fsr2 == 1){
   if(fsrConductance1 > fsrConductance2){
     fsr1 = 1;   //Head in center
     fsr2 = 0;
     fsr3 = 0;
   }
   else{
     fsr2 = 1;   //Head in left
     fsr1 = 0;
     fsr3 = 0;
   }
  }
```

```
if(fsr1 == 1 && fsr3 == 1){
  if(fsrConductance1 > fsrConductance3){
    fsr1 = 1;   //Head in center
    fsr2 = 0;
    fsr3 = 0;
  }
  else{
    fsr3 = 1;   //Head in right
    fsr1 = 0;
    fsr2 = 0;
  }
}

if(fsr2 == 1 && fsr3 == 1){
  if(fsrConductance2 > fsrConductance3){
    fsr2 = 1;   //Head in left
    fsr1 = 0;
    fsr3 = 0;
  }
  else{
    fsr3 = 1;   //Head in right
    fsr1 = 1;
```

```
    fsr2 = 0;
   }
  }

  //Assuming suddenly all fsr detect pressure
  if(fsr1 == 1 && fsr2 == 1 && fsr3 == 1){
   if(fsrConductance1 > fsrConductance2 && fsrConductance1 > fsrConductance3){
    fsr1 = 1;   //Head in center
    fsr2 = 0;
    fsr3 = 0;
   }
   else if (fsrConductance2 > fsrConductance1 && fsrConductance2 >
fsrConductance3){
    fsr2 = 1;   //Head in left
    fsr1 = 0;
    fsr3 = 0;
   }
   else{ //(fsrConductance3 > fsrConductance1 && fsrConductance3 > fsrConductance2)
    fsr3 = 1;   //Head in right
    fsr1 = 0;
    fsr2 = 0;
   }
  }
```

```
  Serial.println(fsr1);

  Serial.println(fsr2);

  Serial.println(fsr3);

  Serial.println(temp);

  Serial.println(humi);


  delay(2000);

}
```

Python Script: main.py

```
import serial
import datetime, time
from datetime import date
from time import sleep
import time
import os
import sys
import threading
from ubidots import ApiClient
import csv

arduino = serial.Serial('/dev/ttyUSB0', 115200)
now = datetime.datetime.now()

#Variables
measurement_loop = 1
pass_loop = 0
toss_counter = -1
start_record = 0
previous_fsr = 0
current_fsr = 0
temp_avg =[] #empty array for temp
temp_total = float(0)
humi_avg =[] #empty array for humi
humi_total = float(0)
delay_a = 0
delay_b = 0

#Ubidots API
api = ApiClient(token='A1E-ZPfcEChQ5WHaTkiw1lza1EuXi42WHG')
```

```
ubi_sleep_awake = api.get_variable('5e92ea0659163630f928d536')
ubi_sleep_awake.save_value({'value': 0.0})
sleep_mode = ubi_sleep_awake.get_values(1)
check_loop = ubi_sleep_awake.get_values(1)

if check_loop[0]['value'] == 0.0:
    pass_loop = 1
else:
    pass_loop = 0

#Upload data for sleep/awake mode data only
def up_startsleep():
    global sleep_mode
    sleep_mode = ubi_sleep_awake.get_values(1)
    exit()

#Upload data for continuous data only
def up_conti():
    ubi_temp = api.get_variable('5e91f504591636112ba25d0b')
    ubi_humi = api.get_variable('5e91f526591636112ba25d0c')
    ubi_temp.save_value({'value': temp_per_time})
    ubi_humi.save_value({'value': humi_per_time})
    exit()

#Upload data for final/total data only
def up_final():
    ubi_temp_total = api.get_variable('5e95cb9b591636683691c7b6')
    ubi_humi_total = api.get_variable('5e95cbc3591636683691c7bd')
    ubi_temp_total.save_value({'value': temp_total})
    ubi_humi_total.save_value({'value': humi_total})
    ubi_toss = api.get_variable('5e95cbed591636683691c7ca')
```

```
    ubi_toss.save_value({'value': toss_counter})
    exit()

while True:
    up_startsleep_data = threading.Thread(target=up_startsleep)
    up_startsleep_data.start()

    if pass_loop == 1:
        # when user press button to sleep
        if sleep_mode[0]['value'] == 1.0:
            if (start_record == 0):
                #record startsleep
                startsleep_time = now.strftime("%H%M%S")
                ubi_startsleep_time = now.strftime("%H:%M:%S")
                print(startsleep_time)
                start_record = 1    #recorded startsleep
                start = time.time()

            else:
                #record all measurement continuous
                measurement_loop = 0
                fsr1 = arduino.readline()
                fsr2 = arduino.readline()
                fsr3 = arduino.readline()
                temperature = arduino.readline()
                humidity = arduino.readline()
                fsr1 = int(fsr1)
                fsr2 = int(fsr2)
                fsr3 = int(fsr3)

                if(delay_a == 0):
```

```
    # Toss counter
    delay_a = 1
    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):
        toss_counter = toss_counter + 1

if(delay_b == 0):
    delay_b = 1
    temp_per_time = float(temperature)
    temp_avg.append(temp_per_time)
    humi_per_time = float(humidity)
    humi_avg.append(humi_per_time)
    # print(temp_per_time)
    # print(humi_per_time)

    # upload up_conti data
    up_conti_data = threading.Thread(target=up_conti)
    up_conti_data.start()

print(fsr1)
print(fsr2)
print(fsr3)
```

```
            print(toss_counter)
            print("******************")

            #For testing interval
            #sleep(2)
            #For 5 min interval
            sleep(300)

        #when user press button to awake
        elif sleep_mode[0]['value'] == 0.0 and measurement_loop == 0:
            # upload up_final data
            up_final_data = threading.Thread(target=up_final)
            up_final_data.start()

            #record endsleep
            end = time.time()
            elapsed = end - start
            #hours = elapsed//3600
            #elapsed = elapsed - 3600*hours
            #minutes = elapsed//60
            #seconds = elapsed - 60*minutes
            #sleepduration = '%d%d' %(hours,minutes)
            sleepduration = time.strftime("%H%M%S", time.gmtime(elapsed))
            print(sleepduration)

            #calculate the total avg of temp and humi per 5min
            temp_total = sum(temp_avg)
            temp_total = temp_total / len(temp_avg)
            print("%.2f" % temp_total)
            humi_total = sum(humi_avg)
            humi_total = humi_total / len(humi_avg)
```

```
        print("%.2f" % humi_total)

        # export data to CSV file
        with open('yesterday_night.csv', mode='w') as csv_file:
            writer = csv.writer(csv_file, delimiter=',',
                                quotechar="", quoting=csv.QUOTE_MINIMAL)

        with open('yesterday_night.csv', mode='w') as csv_file:
            fieldnames = ['Toss', 'StartSleep', 'SleepDuration', 'Avg.Temp', 'Avg.Humi']
            writer = csv.DictWriter(csv_file, fieldnames=fieldnames)
            writer.writeheader()
            writer.writerow({'Toss': toss_counter, 'StartSleep': startsleep_time,
                             'SleepDuration': sleepduration, 'Avg.Temp': "%.2f" % temp_total,
                             'Avg.Humi': "%.2f" % humi_total})

        #transfer data to sleep_ml.py
        f = open("transfer.txt", "w")
        f.write(str(toss_counter) + ", " + str(startsleep_time) + ", " + str(sleepduration))
        f.close()

        os.system('python3 sleep_ml.py')

        sleep(5)
        sys.exit()

    else:
        sleep(1)
```

Python Script: sleep_ml.py

```
import sklearn
from sklearn.utils import shuffle
from sklearn.neighbors import KNeighborsClassifier
import pandas as pd
import numpy as np
from sklearn import linear_model, preprocessing
from sklearn.preprocessing import LabelEncoder, OneHotEncoder
import pickle
from ubidots import ApiClient
import threading
import csv

#Ubidots API
api = ApiClient(token='A1E-ZPfcEChQ5WHaTkiw1lza1EuXi42WHG')

def up_ml_predict():
    ubi_sleep_rating = api.get_variable('5e9c220159163638ef52d7c2')
    ubi_sleep_rating.save_value({'value': answer})
    exit()

#Read yesterday night txt file
with open("transfer.txt", "r") as filestream:
    for line in filestream:
        dataline = line.split(",")
        z1 = str(dataline[0])
        z2 = str(dataline[1])
        z3 = str(dataline[2])

#Read sleep_data.csv dataset
data = pd.read_csv("sleep_data.csv", dtype={'StartSleep': object, 'SleepDuration':
```

```
object})
data = data[['Toss', 'StartSleep', 'SleepDuration', 'SleepCondition', 'TotalSleep',
'SleepingTime', 'SleepRating']]

#Convert some string feature to integer label
le = LabelEncoder()
datale = data
datale.SleepCondition = le.fit_transform(datale.SleepCondition)
datale.TotalSleep = le.fit_transform(datale.TotalSleep)
datale.SleepingTime = le.fit_transform(datale.SleepingTime)

predict = "SleepRating"
#X = datale[['Toss', 'StartSleep', 'SleepDuration', 'SleepCondition', 'TotalSleep',
'SleepingTime']]
X = datale[['Toss', 'StartSleep', 'SleepDuration']]
y = data[[predict]]
x_train, x_test, y_train, y_test = sklearn.model_selection.train_test_split(X, y, test_size =
0.2)

'''
#Only run once to get the best accurate trained model.
#And saved in pickle file to save time and resources

best = 0
for _ in range(30):
    x_train, x_test, y_train, y_test = sklearn.model_selection.train_test_split(X, y, test_size
= 0.2)

    model = KNeighborsClassifier(n_neighbors=11)

    model.fit(x_train, y_train.values.ravel())
```

```
    acc = model.score(x_test, y_test)
    print (acc)

    if acc > best:
        best = acc
        #save the best accuracy trained model
        with open("learned_sleep.pickle", "wb") as f:
            pickle.dump(model, f)
'''

#load the already trained best model
pickle_in = open("learned_sleep.pickle", "rb")
model = pickle.load(pickle_in)

#prediction for new sleep data
m = model.predict([[z1, z2, z3]])
answer = int(m)
print (answer)

# upload up_ml_predict data
up_ml_predict_data = threading.Thread(target=up_ml_predict)
up_ml_predict_data.start()
```

Ubidots HTML, CSS, Javascript

HTML

```
<div id="sleeprating_canvas">
        <p id="sleeprating_text"></p>
</div>
```

CSS

```
#sleeprating_text{
  font-family: Trebuchet MS, sans-serif;
  font-size: 25px;
  color: #2fbd68;
  margin: 0 auto;
  text-align: center;
}
```

Javascript

```
var sleeprating_text = $('#sleeprating_text');
var sleeprating;
var lastValue = null;

function giveSleepRating(variableId, token) {
  //Ubidots API to get SleepRating variable data
  var url = 'https://things.ubidots.com/api/v1.6/variables/' + variableId + '/values';
```

```
  $.get(url, { token: token, page_size: 1 }, function (res) {
    if (lastValue === null ||res.results[0].value !== lastValue.value) {
      sleeprating = res.results[0].value;
      lastValue = res.results[0].value;
      if (sleeprating == 0){
        sleeprating_text.text("Your sleeping habit is good...Keep it up. You have good sleeping condition, are sleeping early at night and sufficiant sleeping hours for an adult.");
      }
      else if(sleeprating == 1){
        sleeprating_text.text("You have good sleep condition and are sleeping early at night. You are having insufficiant sleeping hours as 7-9 hours is recommended for an adult.");
      }
      else if(sleeprating == 2){
        sleeprating_text.text("You have good sleep condition and sufficiant sleeping hours for an adult. You are sleeping late at night... Try to sleep before 12:00 AM.");
      }
      else if(sleeprating == 3){
        sleeprating_text.text("You have good sleep condition. You have insufficiant sleeping hours and are sleeping late at night... Try to have 7-9 hours of sleep and sleep before 12:00 AM.");
      }
      else if(sleeprating == 4){
```

```
        sleeprating_text.text("You are sleeping early at night and sufficiant sleeping hours for an adult. You have bad sleep condition...Try to relaxed yourself from any stress during the day.");

      }

      else if(sleeprating == 5){

        sleeprating_text.text("You are sleeping early at night. You have bad sleep condition and insufficiant sleeping hours... Try to relaxed yourself from any stress during the day and have 7-9 hours of sleep.");

      }

      else if(sleeprating == 6){

        sleeprating_text.text("You have sufficiant sleeping hours for an adult. You have bad sleep condition and are sleeping late at night...Try to relaxed yourself from any stress during the day and sleep before 12:00 AM.");

      }

      else if(sleeprating == 7){

        sleeprating_text.text("You have bad sleeping habits. Try to relaxed yourself from any stress during the day, have 7-9 hours of sleep and sleep before 12:00 AM");

      }

      else{

        sleeprating_text.text(" ");

      }

    }

  });

}
```

```
//Ubidots API token

giveSleepRating('5e9c220159163638ef52d7c2', 'A1E-
ZPfcEChQ5WHaTkiw1lza1EuXi42WHG');

setInterval(function () {

 }, 2000);
```

Dataset: sleep_data.csv

Toss,StartSleep,SleepDuration,Avg.Temp,Avg.Humi,SleepCondition,TotalSleep,SleepingTime,SleepRating

12,231723,090628,30.20,74.53,Good,Enough,Early,0

21,234650,093457,30.85,75.51,Good,Enough,Early,0

16,001623,080039,30.85,76.65,Good,Enough,Late,2

45,221451,103217,30.17,75.41,Bad,Enough,Early,4

18,021125,071055,30.08,77.56,Good,Enough,Late,2

26,234802,084419,30.14,74.70,Good,Enough,Early,0

27,235614,093532,30.71,76.82,Good,Enough,Early,0

51,003439,080815,31.89,77.84,Bad,Enough,Late,6

17,012205,071147,30.54,75.07,Good,Enough,Late,2

21,231457,090119,31.91,75.51,Good,Enough,Early,0

33,002222,091830,31.32,76.45,Good,Enough,Late,2

39,010342,085348,32.10,77.52,Bad,Enough,Late,6

43,003639,074542,30.31,77.42,Bad,Enough,Late,6

19,234256,080311,30.66,77.71,Good,Enough,Early,0

27,024919,052139,30.57,76.15,Good,Lack,Late,3

36,022628,051957,30.00,75.34,Good,Lack,Late,3

25,003317,085322,31.54,77.27,Good,Enough,Late,2

19,234703,085549,30.88,76.14,Good,Enough,Early,0

24,003759,071131,31.85,75.08,Good,Enough,Late,2

17,011631,063409,32.09,76.69,Good,Lack,Late,3

38,021155,080145,29.99,76.35,Bad,Enough,Late,6

26,004823,073436,30.07,75.02,Good,Enough,Late,2

24,012317,062012,31.31,77.44,Good,Lack,Late,3

18,001529,084045,30.11,76.91,Good,Enough,Late,2

28,002601,085076,30.79,76.82,Good,Enough,Late,2

24,011028,091512,30.31,77.71,Good,Enough,Late,2

31,234833,091533,30.52,77.86,Good,Enough,Early,0

29,030229,051007,30.97,77.75,Good,Lack,Late,3

16,023819,061744,30.99,77.45,Good,Lack,Late,3

47,004328,083558,30.24,75.65,Bad,Enough,Late,6

25,234657,085326,31.62,76.40,Good,Enough,Early,0

46,001829,085956,30.82,74.91,Bad,Enough,Late,6

28,010619,074812,31.23,77.66,Good,Enough,Late,2

14,003622,071134,29.98,76.24,Good,Enough,Late,2

39,002407,071846,30.20,77.76,Bad,Enough,Late,6

48,011938,070904,31.46,77.10,Bad,Enough,Late,6

41,005125,093152,31.67,76.97,Bad,Enough,Late,6

16,234654,100633,30.52,75.09,Good,Enough,Early,0

29,003646,071701,31.09,76.07,Good,Enough,Late,2

31,005851,071622,31.16,76.83,Good,Enough,Late,2

24,022818,054859,29.99,76.82,Good,Lack,Late,3

17,020629,071542,30.02,77.29,Good,Enough,Late,2

29,235836,074836,30.78,77.89,Good,Enough,Early,0

35,004117,070824,30.11,77.43,Good,Enough,Late,2

12,003703,075153,30.76,76.50,Good,Enough,Late,2

42,030638,051310,31.55,75.36,Bad,Lack,Late,7

31,014617,070309,30.04,77.30,Good,Enough,Late,2

47,225922,100746,29.90,75.03,Bad,Enough,Early,4

27,004817,075029,30.58,75.54,Good,Enough,Late,2

13,003138,084014,30.81,77.71,Good,Enough,Late,2

25,010956,071532,30.55,76.43,Good,Enough,Late,2

27,004848,075422,30.77,75.75,Good,Enough,Late,2

33,003608,071006,30.05,75.17,Good,Enough,Late,2

26,011319,064923,30.97,75.36,Good,Lack,Late,3

52,234347,084908,29.91,76.99,Bad,Enough,Early,4

49,001635,085144,30.25,75.73,Bad,Enough,Late,6

23,023249,060616,31.60,75.91,Good,Lack,Late,3

16,004750,071157,30.71,76.59,Good,Enough,Late,2

28,012147,065831,31.49,77.36,Good,Lack,Late,3

39,001309,093301,29.98,75.22,Bad,Enough,Late,6

Poster

Prepared by: **WONG KAH WAI**

IoT-Based Sleep Analysis Using Machine Learning Technique

In recent year(s), the term IoT short for Internet of Things has become a hot topic in most technologies field. As stated, IoT can do what previous generation technologies can not achieve which is combining the electronic and communication field together. IoT is a technology that can interconnect people and any machine that is connected to the internet.

MAIN OBJECTIVES

- Provide a sensor-based measurement of the sleep data of the user.
- Implement machine learning technique into the product system. Utilizing the machine learning technique, the product is able to classify the sleep data into sleep rating,

FYP BY:

Supervisee: WONG KAH WAI
Supervisor: MR. TEOH SHEN KHANG

PROBLEM STATEMENT

- Sleep disorder faced by humans.
- A need for a sleep monitoring device.

KEY STRENGTHS

- IoT and Machine Learning capability.
- IoT allows user to control the smart pillow and view its data.
- Machine Learning allows the user to know his sleep rating through the prediction model.

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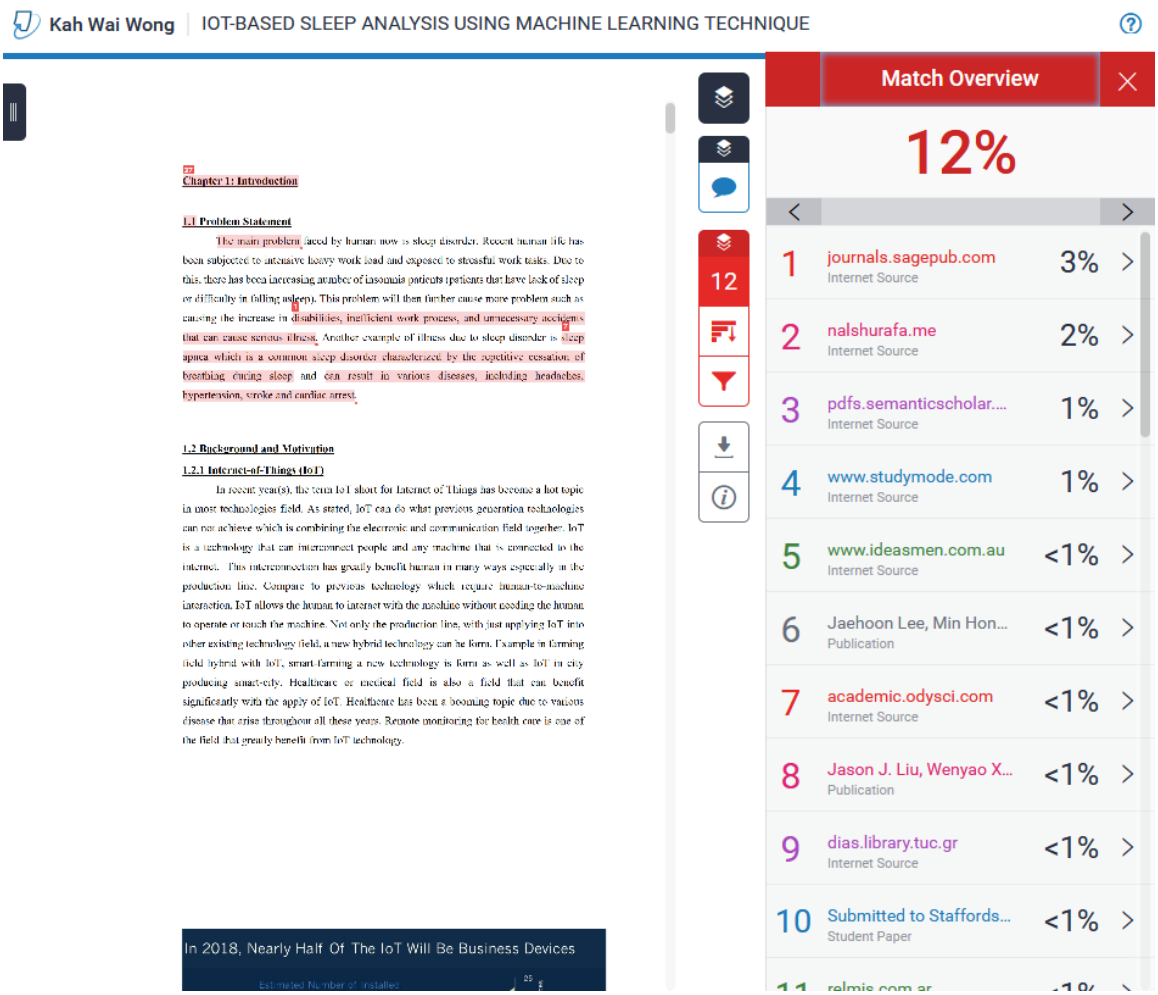
Kah Wai Wong | IOT-BASED SLEEP ANALYSIS USING MACHINE LEARNING TECHNIQUE
Chapter 1: Introduction
1.1 Problem Statement
The main problem faced by human now is sleep disorder. Recent human life has been subjected to intensive heavy work load and exposed to stressful work tasks. Due to this, there has been increasing number of insomnia patients (patients that have lack of sleep or difficulty in falling asleep). This problem will then further cause more problem such as causing the increase in disabilities, inefficient work process, and unnecessary accidents that can cause serious illness. Another example of illness due to sleep disorder is sleep apnea which is a common sleep disorder characterized by the repetitive cessation of breathing during sleep and can result in various diseases, including headaches, hypertension, stroke and cardiac arrest.
1.2 Background and Motivation
1.2.1 Internet-of-Things (IoT)
In recent year(s), the term IoT short for Internet of Things has become a hot topic in most technologies field. As stated, IoT can do what previous generation technologies can not achieve which is combining the electronic and communication field together. IoT is a technology that can interconnect people and any machine that is connected to the internet. This interconnection has greatly benefit human in many ways especially in the production line. Compare to previous technology which require human-to-machine interaction, IoT allows the human to interact with the machine without needing the human to operate or touch the machine. Not only the production line, with just applying IoT into other existing technology field, a new hybrid technology can be form. Example in farming field hybrid with IoT, smart-farming a new technology is form as well as IoT in city producing smart-city. Healthcare or medical field is also a field that can benefit significantly with the apply of IoT. Healthcare has been a booming topic due to various disease that arise throughout all these years. Remote monitoring for health care is one of the field that greatly benefit from IoT technology.
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