"BEDRUNN3R: *An Intelligent Running Alarm Clock"*

by

Lee Kien Ee

16152

A dissertation submitted to the
Information and Communication Technology Programme
Universiti Teknologi PETRONAS
In partial fulfillment of the requirement for the
BACHELOR OF TECHNOLOGY (Hons)
(INFORMATION & COMMUNICATION TECHNOLOGY)

MAY 2015

Universiti Teknologi PETRONAS

Bandar Seri Iskandar

32610 Tronoh

Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

BEDRUNN3R: ***An Intelligent Running Alarm Clock***

by

Lee Kien Ee
16152

A project dissertation submitted to the
Information & Communication Technology Programme
Universiti Teknologi PETRONAS
In partial fulfillment of the requirement for the
BACHELOR OF TECHNOLOGY (Hons)
(INFORMATION & COMMUNICATION TECHNOLOGY)

Approved by,

_____
(DR. NORSHUHANI BT ZAMIN)

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

MAY 2015

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

_____

LEE KIEN EE

ABSTRACT

The conventional alarm clocks have been serving their purpose to mankind since their inception, to wake people up every single morning. However, the rates of oversleeping are still on the rise and people are having trouble waking up in the morning even with the use of alarm clocks. The snooze button that is available on all conventional alarm clocks provide user with more sleep but at a cost of deteriorating their quality of health and exacerbating sleep inertia at the same time.

The objective of this project is to study the problems associated with sleep that are often faced by people and to conduct a comparative study on existing intelligent alarm clocks in the market that functions using movement. Then, to solve the problems studied, an intelligent moving alarm clock that implements the application of artificial intelligence will be developed. The prototype of this alarm clock will also be tested against the usage of traditional and conventional alarm clocks.

The Hypothetico-Deductive method will be used as the development methodology of this project and the prototyping phase will be following the Rapid Application Development (RAD) model. The development methodology will be used alongside some other research methodologies to develop the system flows and architectures.

The V-Model will be used to evaluate the performance and viability of the system in the real-world environment. The test results will indicate the effectiveness of the system to determine if it surpasses the conventional alarm clocks and can be used as a replacement. The test cases will be designed using different room architectures and different situations in order to make sure all aspects and factors are tested.

With the development of BEDRUNN3R, it is hoped that it will ease people in waking up in the morning and sleep-related problems will soon be a problem of the past. Recommendations for continuation and future work of this project are also included.

ACKNOWLEDGEMENT

First and foremost, I would like to extend my deepest gratitude to my supervisor, Dr. Norshuhani binti Zamin for her unwavering guidance, support, ideas, motivation and not to mention, patience throughout the duration of the entire project. Her supervision and care has nurtured not only me, but everyone under her well and brought them forward along this great journey, one step forward at a time. I would also like to thank my co-supervisors, Dr. Izzatdin bin Abdul Aziz and Mr. Radzi bin Zainol for sharing their experience and invaluable knowledge in enhancing this project.

My deepest appreciation goes to Universiti Teknologi PETRONAS (UTP) and the Department of Computer and Information Sciences (CIS) for providing the state-of-the-art infrastructure and tools, which stand crucial to the development of this project.

My sincere appreciation also extends out to my family members, friends, lab mates and also teammates from the RoboHOLIC Club for being all the while supportive towards the development of my project. Without their faith and moral support, I would not have been able to achieve what I did during this first phase of Final Year Project and with their ideas and insights, I was able to achieve more objectives in the same period of time.

Lastly, my greatest pleasure goes to acknowledge the efforts of the many people who directly or indirectly contributed toward the accomplishment of this project. Without their support, completing this project would have been difficult and taken up much more time than expected.

Thank you all again.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1
INTRODUCTION

1.0 Background of Study

Every living person on this globe share one common first thing that they all have to do every single day; waking up. Even though it may sound simple, some people find it hard to wake up on time in the morning, especially for heavy sleepers. They oversleep and end up getting to work, classes or lectures late or even worse, missing out on important events in their life. The number of workers coming late to work are increasing and this incurs a loss to the company and nation via productivity lost. Students, our hope for the future are missing important lectures and tutorials for a simple reason because they overslept. Although alarm clocks have been developed to help combat this problem, they are still unable to stop people from oversleeping and smarter, effective alarm clocks are needed. Therefore, one question exists; how can current engineering and technology assist to curb this problem? By applying my knowledge in Artificial Intelligence and robotics, I hope to be able to design an innovative and exciting way to develop a smart alarm clock as a solution to this situation.

1.1 Problem Statements

There are two major problems that have been identified with the current sleeping habits of most people that has led to the inception of this project.

1.1.1 Oversleeping

Firstly, there is a problem of oversleeping that has been around for a long period of time and it is a common problem which affects everyone. Conventional alarm clocks that are in the market now are not any more effective in forcing heavy sleepers out of bed and their effectiveness have dropped as they can often be turned off easily if they are within reach of the user. This problem is negatively impacting everyone as oversleeping reduces productivity of both workers and students alike because precious time is wasted on sleeping.

1.1.2 Excessive Snoozing Leading to Sleep Fragmentation

Apart from that, there is also a problem of sleep fragmentation that happens when the snooze button on alarm clocks is used excessively. The conventional alarm clocks in the market still allows users to press the snooze button for as much extra sleep as they want and they are unaware of the health problems will occur to them. Sleep fragmentation brings adverse effects to the human body such as hormonal imbalance, impaired daytime function, decreased reaction time, reduced short term memory, increased sleep inertia and increased blood pressure. Users who use the snooze button frequently often report of feeling tired and having decreased productivity at work and in school.

1.2 Objectives

The objectives for this project have been identified as follows

1. To study the problems associated with sleep that are often faced by people.
2. To conduct a comparative study on existing moving alarm clocks in the market.
3. To develop an intelligent moving alarm clock that implements the application of artificial intelligence to solve the problems studied in (1) and (2).
4. To test the prototype against the usage of traditional and conventional alarm clocks.

1.3 Scope of Studies

For this project, the scope of my studies is decided based on several factors, which will each be explained further. For the target group of this project, it is limited to students, including school students, college students and also university students. The reason for this is due to time and location factors. As a student myself, it is more feasible and accessible to conduct my studies or research within the university itself and this allows me to focus more on a specific user group to obtain a higher accuracy in my findings. Students are also the group with the most irregular sleeping hours, and have the highest tendency to have sleeping problems. As for the development of this project, the system prototypes will be developed using LEGO Mindstorms EV3 while the final product is to be built using Arduino. The reason for this is because LEGO allows for easier hardware development and allows for easy customization and changes to the prototype. It also allows me to focus more on the software part and algorithm, which is the main research element in the project, instead of spending more time on the hardware compared to the software which would be the case if Arduino is used.

For the space of robot navigation, it is set within a dimension of 5m x 5m as from the observation made in the student rooms of Universiti Teknologi PETRONAS (UTP) and Multimedia University (MMU), I found out that this is the average room size. From the results of the observation too, I have set the scope for the obstacles to be limited to small objects commonly found in student rooms such as shoes and bottles.

CHAPTER 2
LITERATURE REVIEW

2.0 Introduction

In this chapter, literatures and researches done by previous researchers in the fields related to this project are studied, analyzed and reviewed. The literatures range from the topics of Artificial Intelligence (AI) and also sleep related fields such as oversleeping, sleep fragmentation and sleep cycles, and the reviewed literatures are discussed.

2.1 Oversleeping

In this era of technology, a common problem has become more and more prevalent in our everyday lives but is often overlooked as a trivial matter. Oversleeping, or as defined by The Free Dictionary (n.d.), refers to an intentional or unintentional act of sleeping beyond one's intended time for waking or intended time for getting up. Regardless of age, race, background and gender, everyone is subjected to the risk of oversleeping in the morning, especially if they do not have a proper sleeping pattern or do not have enough sleep regularly (McKibben, 2014). This statement is supported by Cheng (2003), stating that in Japan, about half of the students in senior high schools are sleeping less than 6 hours during weekdays. Their sleeping pattern have been altered as a result of the habit of staying up late to do work and to study for tests. The National Sleep Foundation (n.d.) also states that by not having a regular sleep pattern, students are unintentionally altering their biological clock and this hurts their sleeping quality and subject them to higher risks of oversleeping in the morning. According to the results of the CDC's Youth Risk Behavior Survey in 2011 and 2013, high school students in the United States are not having a regular and ample amount of sleep, with

69% of the students sleeping less than 8 hours a day and 40% sleeping less than 6 hours. Another poll by National Sleep Foundation also recorded that 59% of 6th to 8th graders and 87% of U.S. high school students were getting less than the recommended 8.5 to 9.5 hours of sleep on weekdays.

2.2 Effects of Oversleeping

Oversleeping may not seem to have a huge impact on the society, but researches done have proven otherwise. According to a research done by Onepoll in 2007 in the United Kingdom, 28.1 million or 97% of the British workforce are not getting enough sleep at night during workdays and has subsequently, affected their ability to wake up on time to work in the morning. On average, 49% of the British workers clock in to work late every day and 20% of these workers do so due to having overslept. Munnelly (2007) mentions that this is significantly affecting the productivity of business in the United Kingdom, and oversleeping is costing the country a staggering amount of £619 million or RM3.36 billion a year in terms of productivity lost.

The National Institutes of Health (n.d.) claims that those who oversleep more will tend to rely more heavily on alarm clocks. They are also the ones who tend to use the snooze button excessively in order to get every little amount of extra sleep that they can get before starting the day. This raises another health concern as excessive snoozing will subsequently lead to fragmented sleep or sleep fragmentation.

2.3 Sleep Fragmentation and Sleep Cycle

According to Sleepnet (n.d), sleep fragmentation can be defined as the interruption of the sleep stage as a result of the appearance of a lighter sleep stage or due to waking up. In its natural state, sleep can be divided into 5 stages, which is stage 1, 2, 3, 4 and Rapid Eye Movement (REM) sleep. Stages 1 to 4 are grouped under Non-Rapid Eye Movement (NREM) sleep and stages 3 and 4 are referred to as deep sleep. These sleep stages progress cyclically from 1 through REM then restart again with stage 1. A complete sleep cycle takes an average of 1.5 hours to 2 hours. The first sleep cycles

each night have a shorter REM period with longer periods of deep sleep but as the night progresses, the REM period lengthen and deep sleep time decreases.

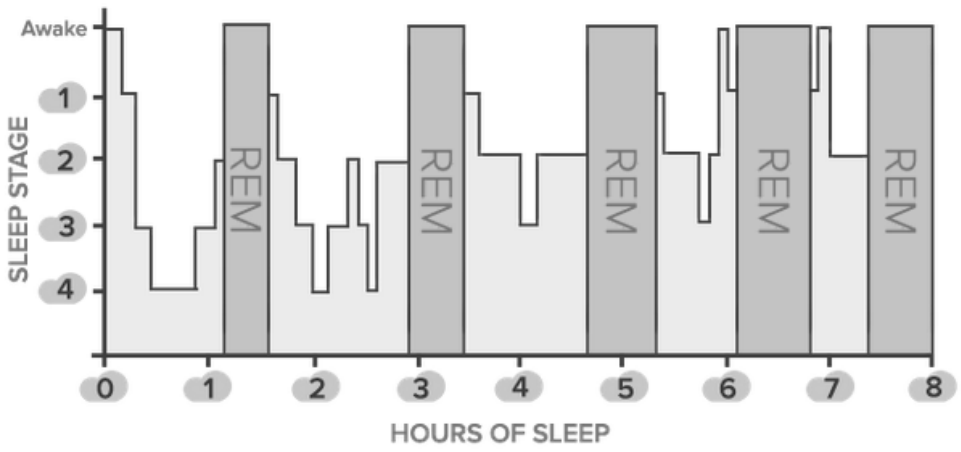


Figure 2.1: Stages of a healthy sleep (Centre for Sound Sleep, 2015).

The first stage of sleep, Stage 1 is also called light sleep and during this period, people are drifting in between sleeping and being awake and can be woken up easily. Eyes move slowly during this stage and muscular activities slow down. Meanwhile in stage 2, the eyes stop moving, brain waves become slower and random bursts of rapid brain waves occur. Stage 3 comes after that, and extremely slow brain waves known as delta waves are interspersed with smaller and faster waves. In stage 4, only delta waves are released by the brain and this is why stages 3 and 4 are known as delta sleep or deep sleep. Deep sleep is when muscle and eye activity stop completely and waking up is very difficult to do.

During Rapid Eye Movement (REM) sleep, the body prepares itself to wake up. Hormones are released, heart rate quickens and breathing rate goes back to normal. If a person does not wake up after REM, the body restarts the sleep cycle. Slow wave sleep (SWS) comes mostly in the first half of the night while REM mostly in the second half. Natural waking usually occurs after REM (Centre for Sound Sleep, 2015).

It is important that the natural sleep cycles are not interrupted as some stages prepares the body for sleep while some prepares it for waking up. Waking up from a deeper stage of sleep will leave a person feeling refreshed while waking up from earlier stages

of sleep will leave the person feeling groggy and tired. This happens because interrupted or fragmented sleep causes the sleep cycle to immediately stop and if the person goes back to sleep after, the sleep cycle does not continue from where it left off, but rather the cycle restarts at an earlier stage. Thus, instead of waking up from a deeper stage of sleep which prepares the body to wake up, the person is woken up from earlier stages of sleep which does the complete opposite, making it worse for the person (AsapSCIENCE, 2013).

2.4 Effects of Sleep Fragmentation

Bonnet & Arand (2003) claim that excessive sleep fragmentation can lead to various health concerns. Among the clinical effects of sleep fragmentation include increased objective sleepiness, decreased mental performance, decreased reaction time, decreased alertness, hormonal effects, pulmonary effects, and many more. Davies et. al (2003) also found that subjects of fragmented sleep experienced increases in blood pressure up to a degree of 75 percent. Stepanski (2002) supports Bonnet & Arand's claim by stating the fact that fragmented sleep have a less restorative effect compared to interrupted sleep and instead of making a person feel better, it does the complete opposite. Stepanski's research on sleep fragmentation proves that sleep fragmentation causes a higher degree of sleepiness and daytime-function impairment after waking up.

The effects of sleep fragmentation can pose a threat on students as most lectures and classes start early in the morning and their daytime function is impaired, it will have a significant effect on their performance in school. According to McKibben (2014), about 30% and 6% of high school and middle school students respectively report of a high degree of sleepiness in school and they fall asleep in classes every day. A similar research done by Cheng (2003) showed similar results with approximately half of the 501 junior high school students doze off in classes more than twice in a single week.

2.5 Artificial Intelligence

According to Jones (2008), Artificial Intelligence or more commonly known as AI, is the field of study where computers or computer-based systems are taught or made to replicate intelligence found in human beings. Since its inception in the early 1950s, interest in the field of AI begun to increase among scholars and scientists alike, even more after a British Scientist, Alan Turing published a paper on Computing Machinery and Intelligence. He was a man who had high influence in the development of computer science and developed the Turing machine which then became a model for general purpose computer. Turing formalized the concept of algorithm and computation and is widely accepted in the public eye as the father of Artificial Intelligence.

The main focus of Artificial Intelligence is to create or develop computers which can perform tasks commonly associated with intelligent beings (Russel & Norvig, 2013). The field of AI can be broken down into separate research groups, such as machine learning, natural language processing (NLP), expert system, fuzzy logic, computational biology and many others. By combining all these research groups, researchers hope that AI can be applied to solve real-world problems where computers or robots can solve problems with little or no human intervention. As mentioned by Dr. Dickson Lukose, the Director of Artificial Intelligence Department in MIMOS, the ultimate goal of AI is to create computers that "know what to do when what to do is not known". Currently, active research is being conducted in areas such as estimation theory, mobility mechanisms, multi-agent negotiation, natural language interfaces, machine learning, expert systems, active computer vision, probabilistic language models for use in spoken language interfaces, and the modeling and integration of visual, haptic, auditory and motor information.

2.6 Existing Moving Alarm Clocks

A variety of alarm clocks have been designed by using movement as a basis to wake users up with a higher effectiveness. A list of such alarm clocks that have been developed and are already in the market will be discussed in this section.

Figure 2.2: Clocky and Tocky (Nanda Home, 2008)

Clocky is a moving alarm clock that was created by Nanda Home. It moves by rolling on its two wheels that are located at the side of its body. Meanwhile, Tocky, the elder brother of Clocky, does not have any wheels but moves by rolling using its body as a ball. Both Clocky and Tocky are activated once the user presses the snooze button for the second time and move by using a random algorithm to determine its direction of movement. While it is moving, Clocky uses sensors to locate small obstacles in its path and to then avoid them but Tocky does not. Clocky and Tocky move randomly around the room while sounding the alarm and forces the user to find them to turn off the alarm. The disadvantages of both Clocky and Tocky is that they are not smart in hiding from the user and they may turn off accidentally while moving (Nanda Home, 2008).

Figure 2.3: Puzzle Alarm Clock (Perpetual Kids, n.d.)

The Puzzle Alarm Clock, developed by Perpetual Kids does not move but rather, uses movement to fire out three puzzle pieces of different shapes and sizes. At the time of the alarm, the alarm clock sounds the alarm and immediately shoots out the puzzle pieces, scattering them all around the alarm clock randomly. To turn off the alarm, the user has to find all three puzzle pieces and fit them back into their slots on the alarm clock. The disadvantages of this alarm clock is that the user will get used to it after some time and the puzzle pieces are very easy to find (Perpetual Kids, n.d.).

Figure 2.4: Rocket Launcher Alarm Clock (Perpetual Kids, n.d.)

The Rocket Launcher Alarm Clock, also developed by Perpetual Kids is another movement-based alarm clock that fires out a part of the alarm clock when at the time

of the alarm. The range of this alarm clock is about 1.5 meters and in a 30 degree angle in the direction of the alarm clock. To turn off the alarm, the user will have to find the rocket and fit it back to its port. The disadvantages of this alarm clock is that the location of the rocket is very predictable and can be easily found by the user as the distance is very short (Perpetual Kids, n.d.).

Figure 2.5: Flying Alarm Clock (Tech Tools, n.d.)

The Flying Alarm Clock is an alarm clock, equipped with a detachable propeller that is developed by Tech Tools. It operates almost similarly to the Rocket Launcher Alarm Clock, but it has a higher range and is more unpredictable. At the moment the alarm is sounded, the propeller lifts off and flies randomly high up and lands in a random location around the room. The user will be forced to look for a small propeller in the room in order to put it back in place. The disadvantage of this alarm clock is that it is very easy to lose the propeller and there is a high chance that the propeller will fall above some large cupboards or behind furniture (Tech Tools, n.d.).

The comparative study has been summarized in Table 2.1 on the next page.

Table 2.1: Table of Comparative Analysis among Existing Intelligent Alarm Clocks

No.	Existing Alarm Clock	Advantages	Disadvantages	Intelligent	Snoozing Prevention	Obstacle Avoidance Ability	User Detection Ability	Hiding Ability	Customizability	Dimensions	Cost
1	Clocky (Nanda Home, 2008)	• Simple design • Small	• Fragile • Only able to move randomly • Volume is not adjustable • Might turn off accidentally	No	No	Yes	No	No	No	14cm x 9cm	RM150
2	Tocky (Nanda Home, 2008)	• Simple design • Small • Able to sustain fall • Able to store and play various music	• Bad user interface • Only able to move randomly • Hard to replace battery • Might turn off accidentally	No	No	No	No	No	No	9cm x 9cm	RM190
3	Puzzle Alarm Clock (Perpetual Kids, n.d.)	• Forces user to think to solve the puzzle • Low cost	• Short distance • Easy to solve • User gets used to it after some time	No	Yes	No	No	No	No	13cm x 5cm	RM95
4	Rocket Launcher Alarm Clock (Perpetual Kids, n.d.)	• Can only be turned off by finding the rocket • Low cost	• Short distance • Predictable	No	Yes	No	No	No	No	7cm x 7cm	RM100
5	Flying Alarm Clock (Tech Tools, n.d.)	• Cool design • Unpredictable • Low cost	• Short distance • The propeller may get lost above or behind furniture	No	Yes	No	No	No	No	7cm x 7cm	RM75

			• Can be turned off without finding the propeller								
6	BEDRUNN3R	• Has artificial intelligence • Follows a rule-based algorithm • Able to look for objects to hide • Able to detect user and to run away • Able to avoid obstacles • Can be customized	• Higher cost (for prototype) • Bigger size (for prototype) • Limited choice of music • Battery must be charged daily (for prototype)	Yes	Yes	Yes	Yes	Yes	Yes	9cm x 6cm	Below RM100, if developed using Arduino

The proposed BEDRUNN3R would contain artificial intelligence, which is not present in any other alarm clocks in the market currently. It will follow a rule-based algorithm which enables it to move autonomously within the room, while minimizing time taken to achieve its goal, which is to hide or run. BEDRUNN3R will also be equipped with the ability to locate hiding spots and to hide itself from the user, making it hard to be found or turned off, a new feature that has yet to be implemented in any moving alarm clocks. It can also utilize its infrared sensor to sense for the user's presence, running away whenever they come too close. To further optimize its performance, BEDRUNN3R is well programmed with an obstacle avoidance algorithm, enabling it to move away from small obstacles that might block its path. Although the cost of BEDRUNN3R is higher, it is only for the prototype that serves as a proof of concept. Once the concept is proven, BEDRUNN3R can be mass produced using Arduino, which will only cost a small fraction of the original cost and at the smaller, sturdier size.

CHAPTER 3
METHODOLOGY

3.0 Introduction

In this chapter, the methodologies used for the development of this project is further discussed. The methodologies can be divided into two, which are the development methodology and the research methodology. The system developed using these methodologies will also be explained in both aspects of the hardware and software.

3.1 Development Methodology

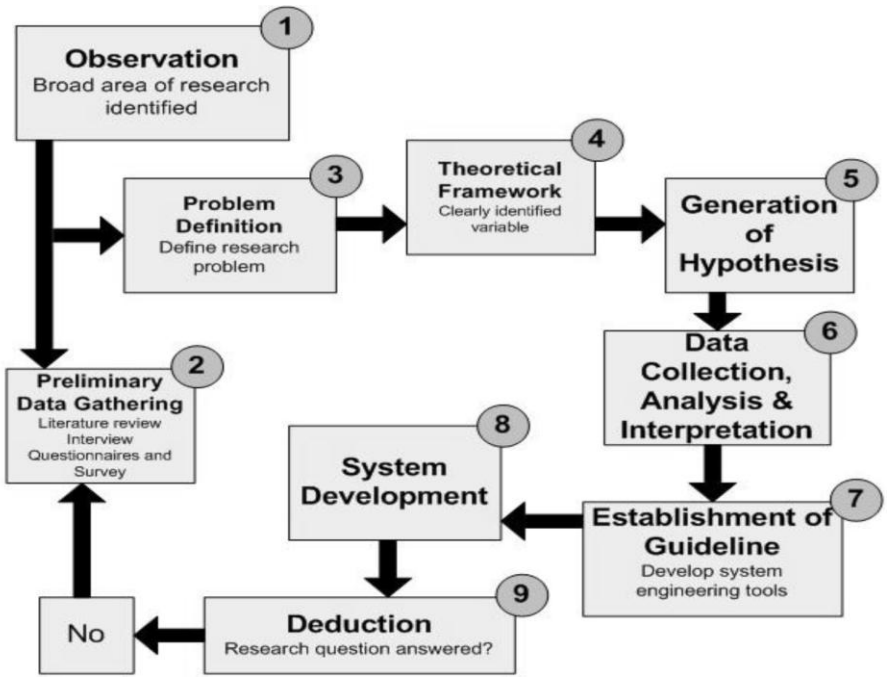


Figure 3.1: The Hypothetico-Deductive Method (Kahome, n.d.)

The Hypothetico-Deductive Method was used throughout the development of this project. Under this deductive method, a hypothesis is first formulated through

scientific inquiry in a form that could possibly be falsified by a test on observable data. Then, falsification takes place, in which a test that could possibly prove the hypothesis wrong is carried out. A test that could but does not run contrary to the hypothesis validates the theory. It is then proposed to compare the explanatory value of competing hypotheses by testing how strictly they are verified by their predictions. If the objectives and hypothesis are not met, the work need to go back to the early phases and the process is started all over again.

3.1.1 Observation

Through observation, it was found that there is a very limited use of Artificial Intelligence (AI) in the design of alarm clocks. In developed countries such as the United States, a company named Nanda Home has started integrating a little bit of intelligence into alarm clocks, but at a very low level. The level of intelligence integrated into the alarm clocks, Clocky and Tocky is only up to the level of being able to avoiding obstacles. The movement of these alarm clocks is not following any algorithms or rules of AI, but rather, is randomized and following a random algorithm.

In Malaysia, it was observed that most students are still using conventional, traditional alarm clocks although smarter moving alarm clocks mentioned previously are already in the market. Therefore, it can be observed that there is a huge potential for the application of AI in moving alarm clocks in Malaysia. It was also found that there are many adverse clinical effects that can be caused by excessive use of the snooze button, which is commonly found in conventional alarm clocks.

3.1.2 Preliminary Data Gathering

The preliminary data gathering was carried out in order to identify the requirements that would serve in the construction of prototypes for BEDRUNN3R. Among the methods used for the preliminary data gathering are internet research, reading journals, articles, research papers, and books, quantitative and qualitative survey. At this point, knowledge needed to proceed with the project are identified. The knowledge required are knowledge in LEGO Mindstorms EV3's hardware and software, Artificial

Intelligence and also rule-based algorithms. LEGO Mindstorms EV3 was chosen to be the platform of choice for the prototype because:

- It allows for easier development in a smaller period of time, which corresponds to the usage of Rapid Application Development (RAD).
- It allows room for creativity, and the design of the prototype can be constantly changed to maximize its effectiveness.
- It allows the developer to put more focus on the programming of the software and algorithm, which is the main research element in the project.
- It is easily customizable, and serves as a good way to experiment on how the final product should look like when it is developed using other cheaper alternatives.

3.1.3 Problem Definition

This phase is where the problem of the study is defined to narrow down the scope of the project. The main focus on this project is to build a moving alarm clock that implements the application of Artificial Intelligence (AI) to solve the problems with conventional alarm clocks. Not one person in this world is free from the risk of oversleeping in the morning, and this is a common problem that is faced by everyone. Although alarm clocks have been created to combat this problem, conventional alarm clocks are less effective in forcing heavy sleepers out of bed as they are within reach of the user and can be easily turned off. Besides, conventional alarm clocks have snooze buttons which are often misused by the users, not knowing the adverse clinical effects that may come with it. Therefore, a moving alarm clock that implements AI will be able to solve all these problems.

3.1.4 Theoretical Framework

In this phase, the narrowed problem has been conceptualized. From the observation and preliminary analysis, the theoretical framework for this project is formulated. The theory in the below figure indicates that the application of Artificial Intelligence in alarm clocks will make it harder for users to turn them off, increase the probability of the user waking up on time and reduce the frequency of use of the snooze button.

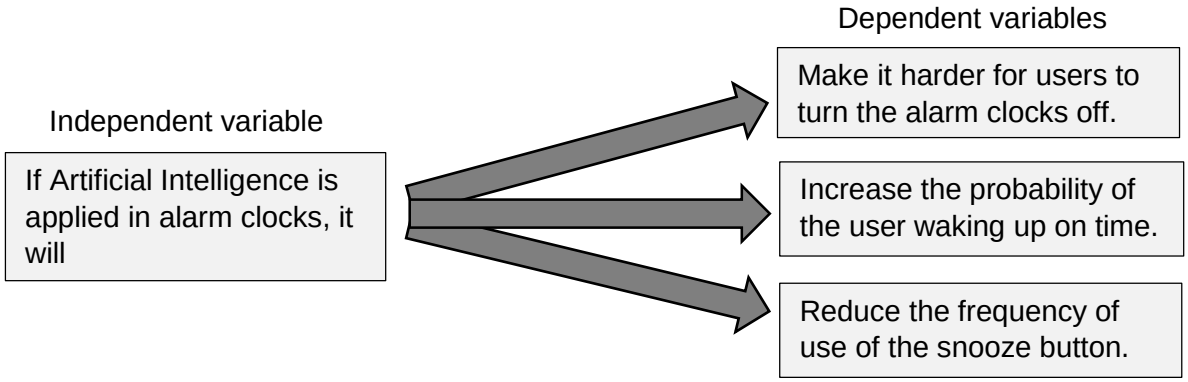


Figure 3.2: The theoretical framework for the project

3.1.5 Generation of Hypothesis

After getting a clear view of the theoretical framework of the project, an early hypothesis is drawn and generated as a baseline to determine whether the project will meet its objectives or not. In order to justify the truth of the hypothesis, the critical variables which are defined in the theoretical framework are put into conditional statement. This statement will be reasoned out during the development and the testing phases of the project.

The formulated hypothesis is, if Artificial Intelligence is integrated into a moving alarm clock, it will make it harder for users to turn them off, increase the probability of the user waking up on time and reduce the frequency of use of the snooze button.

3.1.6 Data Collection, Analysis and Interpretation

Before the development of the prototype is started, necessary and crucial data needs to be gathered and analyzed for the better interpretation of the project. Comparative study on similar products in the market has been carried out to identify features and sensors that will be needed on the new prototype in order to boost effectiveness. The decision is made based on its performance and how it could benefit the prototype in carrying out its task.

Besides, a preliminary qualitative analysis on the target group has also been carried out. A total of 100 respondents comprising entirely of students from Universiti Teknologi PETRONAS (UTP) were surveyed to identify their sleeping habits in the campus. All the respondents were aged from 18 to 25, and come from different nationality, race, religion and gender. Observation is also made on the rooms of student from UTP to identify its layout, placement of objects, types of possible obstacles and also the dimensions of the room.

The results obtained were analyzed to obtain a clearer insight and understanding on the potential users' lifestyle and the actual environment that the prototype would have to be tested in. Based on these information obtained, the algorithm for the prototype can then be figured out to maximize its effectiveness. Additional requirements that the algorithm must have is identified and is tailored to BEDRUNN3R to ensure that it will be able to move smoothly and autonomously.

3.1.7 Establishment of Guidelines

In this project, guidelines has been established to better organize the development and also to easy work during the development phases. Among such guidelines used are flow charts for BEDRUNN3R's algorithm and also the hardware architecture. Every detail of the developed guidelines needs to be fully understood and made unambiguous to ensure the successful development of the prototype.

3.1.8 System Development

The development of this project requires the integration of hardware and software. The development stage goes through quick, successive cycles of prototyping as in Rapid Application Development (RAD).

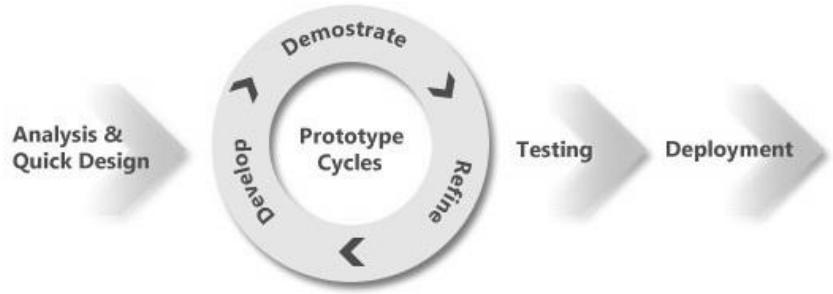


Figure 3.3: The Rapid Application Development (RAD) Model (ISTQB, n.d.)

RAD model is based on the notion that products of higher quality can be developed faster using more expedient processes, such as early prototyping and reusing of software components. The developments in RAD are time-boxed, delivered and assembled into a working prototype. RAD is selected for the development of BEDRUNN3R as it enables prototypes to be produced early in the development phase and with that, feedback can be obtained from target groups, and new requirements for improvement can be elicitated. The newly requirements gathered can then be reflected in the changes made to the previous prototype, and this process continues until a high quality prototype which suits user needs is produced.

The primary focus in RAD is the speed to which prototypes are developed. As more prototypes go through a series of refinement and development, bugs and errors can be removed and potential flaws can be removed before the final product is produced. RAD model suits this project as the project objectives are well-defined and understood and the technical architecture is clear. Under this model, the four main processes involved are requirements elicitation, prototyping, testing and deployment.

Detailed configurations of the hardware and the software or algorithm will be discussed in the next chapter.

3.1.9 Deduction

The final project outcome will be discussed and concluded in the last chapter, Findings and Discussions.

3.2 Research Methodology

Under the research methodology, the algorithm flowcharts, hardware configurations, and tools used in the system will be discussed in more details.

3.2.1 System Flow

The flow of the system algorithm is decided after conducting research on the target group. The algorithm is tailored based on the results of observation done in the target group's rooms. This system focuses on the ability to move and locate low objects such as tables and chairs around the room.

However, there should also be an exception in cases when no low objects are found. There must also be an obstacle detection feature to enable the robot to move away from small obstacles and to continue moving without getting stuck.

The flow of the entire system is divided into 3 parts,

i. Setting Mode
   The mode where the time of the alarm is set.

ii. Hiding Mode
   The default mode, where the robot looks for a low object to hide under.

iii. Running Mode
   The mode that is only activated upon failure to hide during Hiding Mode, and uses infrared sensors to detect the presence of user before running away from him.

Setting Mode

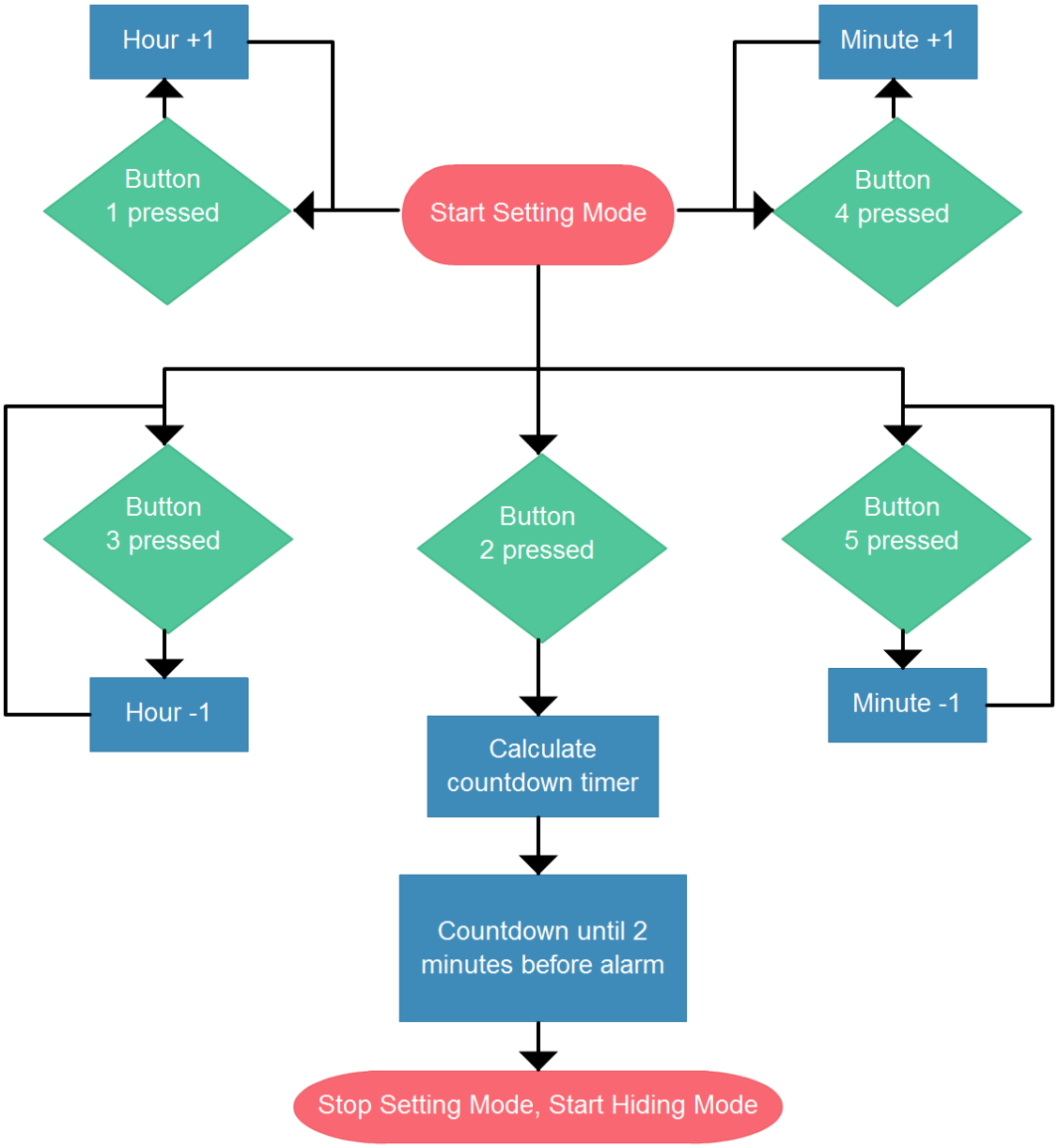


Figure 3.4: Flowchart of Setting Mode

Hiding Mode

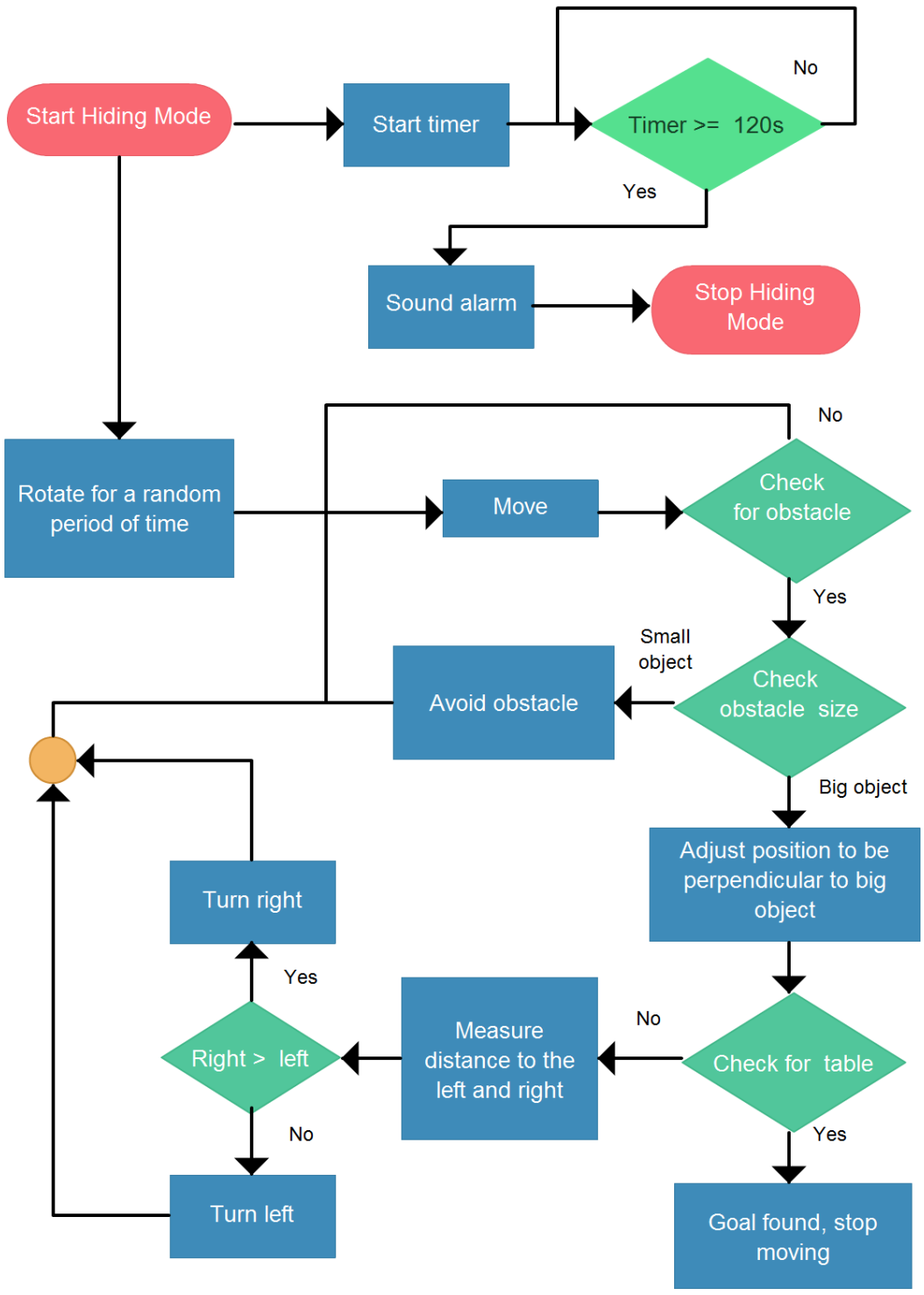


Figure 3.5: Flowchart of Hiding Mode

Running Mode

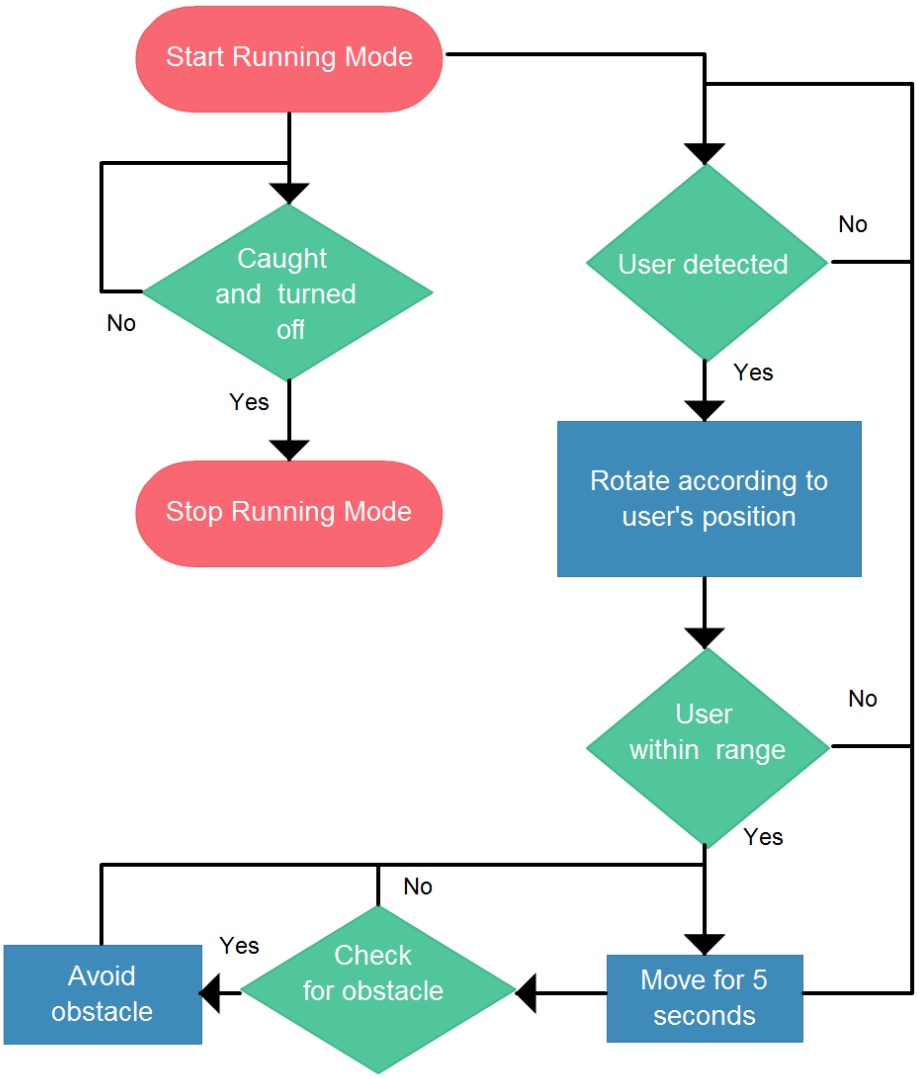


Figure 3.6: Flowchart of Running Mode

3.2.2 Hardware Configuration

The hardware configuration and the port details for the prototype, BEDRUNN3R is shown and described below.

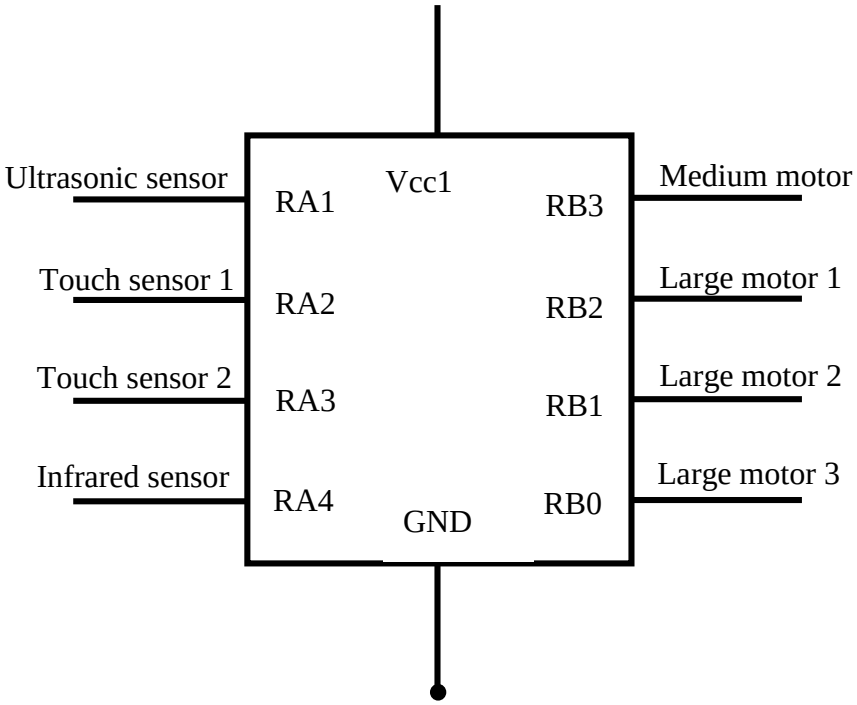


Figure 3.7: PIC Chip Pin Diagram of BEDRUNN3R

Table 3.1: Description of ports used in BEDRUNN3R

Port	Input/Output	Description
RA1	Ultrasonic sensor	Detects proximity of the robot to other objects
RA2	Touch sensor 1	Detects obstacles and allows for positioning of robot to be perpendicular to a wall
RA3	Touch sensor 2	Detects obstacles and allows for positioning of robot to be perpendicular to a wall
RA4	Infrared sensor	Detects proximity to the user with infrared beacon and allows the robot to change its direction depending on the direction of the user

RB3	Medium motor	Rotates the ultrasonic sensor so look in different directions
RB2	Large motor 1	Moves and rotates the robot depending on the current objective
RB1	Large motor 2	Moves and rotates the robot depending on the current objective
RB0	Large motor 3	Rotates the medium motor until the ultrasonic faces upwards to identify low objects

3.2.3 Tools Used

The main tool used for this project is the LEGO Mindstorms EV3. It provides a platform for development for robotics and has been commercialized. The LEGO Mindstorms EV3 comprises of both hardware and software, enabling users to build a robot from scratch using various building parts that are in the Core Set, Expansion Kit and also Development Kit. The robot that is built can then be programmed by using LEGO Mindstorms EV3 software that enables multiple functionalities that correspond to the sensors and motors used. The main components used for BEDRUNN3R is shown in the table below.

Table 3.2: Components of BEDRUNN3R

Component	Description
LEGO Mindstorms EV3 Brick 	The brain of the robot that controls all other components such as sensors and motors. The program is uploaded into the brick via Bluetooth or USB cable and can be run directly from the brick.
Large Motor 	Enables rotation and movement of wheels. BEDRUNN3R uses 3 of this motor for movement and for rotation of the ultrasonic sensor.

Medium Motor 	Enables rotation of parts connected to it. BEDRUNN3R uses this to rotate the ultrasonic sensor in a 360° manner.
Ultrasonic Sensor 	Used to distinguish between small and big objects, identify low objects and determine furthest distance to move.
Infrared Sensor 	Used to detect for the presence of user that is equipped with an infrared beacon. Also used to identify which direction the user is coming from and to position the robot in the opposite direction.
Touch Sensor 	Used to detect small obstacles that cannot be detected by the ultrasonic sensor. Also used to position the robot perpendicular to a wall.

3.3 Evaluation Methodology

After the prototype has been developed, it is tested in order to determine if it meets specified requirements and fulfils its intended functionalities. The testing will be done in stages using the V-Model. The first stage will be unit testing, in which the flow of each of BEDRUNN3R's modes are tested to see if they can function perfectly individually. Then, the second stage, integration testing takes place. During integration testing, the flows of different modes are linked together to see if they can work well together without errors. The testing then proceeds with the third stage, system testing, in which the entire system flow is tested in a test environment, which simulates the actual bedroom environment. The test environment is strictly designed to meet the scope of the project such as in terms of dimension and obstacles used. Once it passes the system testing, the final stage of testing or the acceptance test is carried out. Acceptance testing tests the prototype in the actual environment and in this case, an actual student bedroom with actual obstacles. The prototype's performance will be evaluated and the effectiveness will be tested against conventional alarm clocks. Any rooms for improvement will be noted down and if time permits, changes will be made

to the prototype to improve its performance before the next prototype is released. It will then be tested again using the V-Model and the whole testing phase repeats itself.

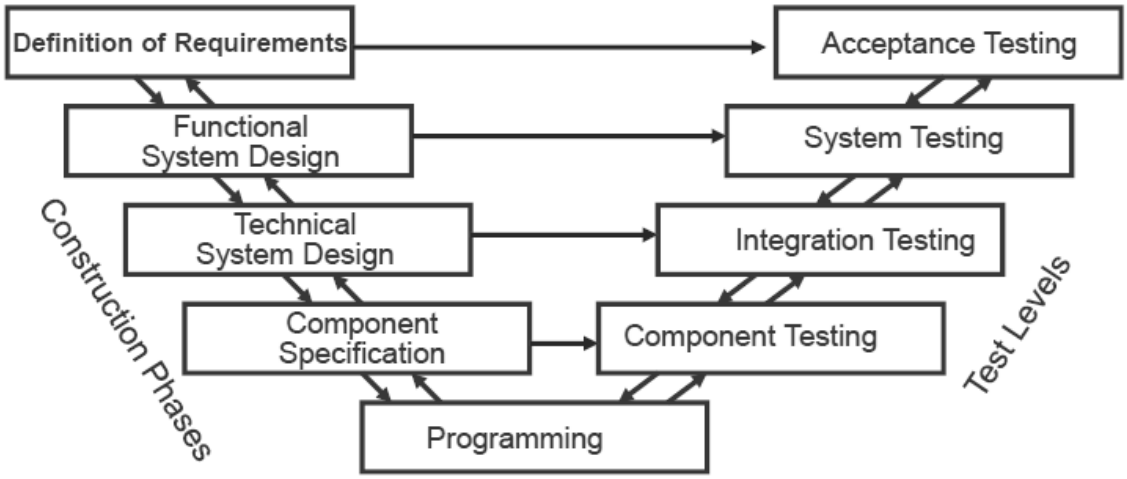


Figure 3.8: The V-Model used in testing of prototypes (ISTQB, n.d.)

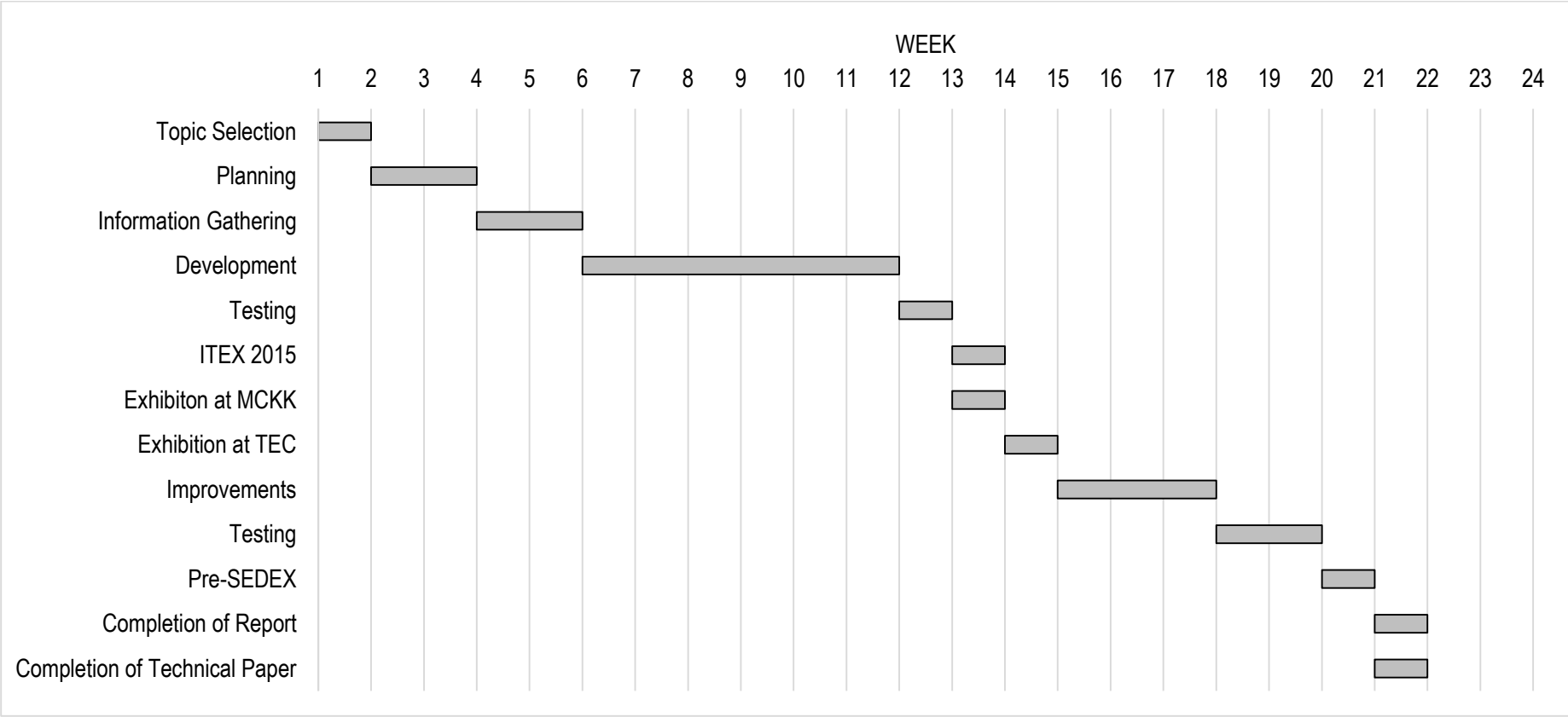


Figure 3.9: Gantt Chart for this project

CHAPTER 4
RESULTS AND DISCUSSION

4.0 Introduction

In this chapter, the outcome of the research done throughout the project such as the preliminary analysis, surveys and interviews are discussed in more details.

4.1 Quantitative Results of Survey

A quantitative survey was carried out among 100 respondents, all comprising of students from Universiti Teknologi PETRONAS (UTP) from between 4th March 2015 to 14th March 2015. The respondents for this survey are chosen from different races, age, gender and also nationality to obtain a diverse range of useful data.

The main purpose for this survey is to serve as a preliminary analysis to understand the current problems, needs and requirements of university students in waking up every morning with conventional alarm clocks and their response towards having a smart, robotic alarm clock in their bedroom. The results obtained will also serve to tell if their current sleeping habits would bring possible adverse clinical effects on their body as researched in the literature review.

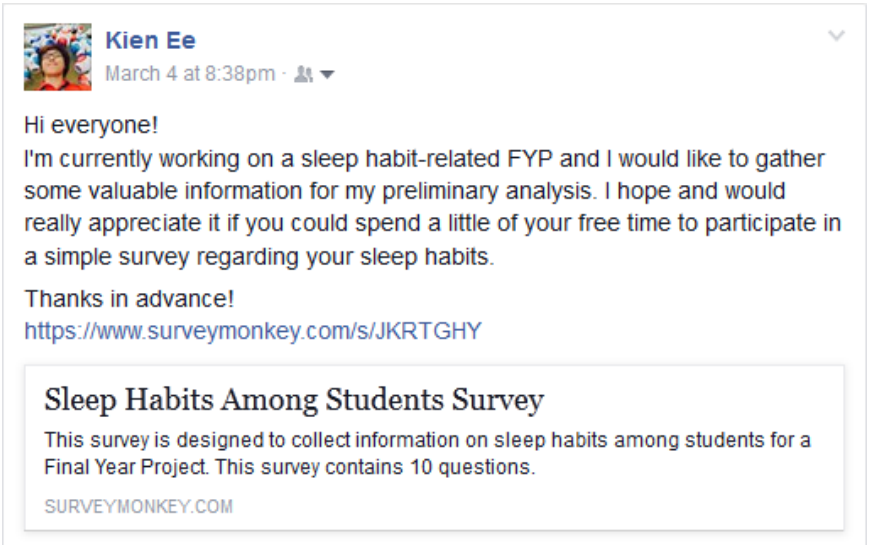


Figure 4.1: Posting done on a social media, Facebook to target specific respondents.

Question 1: How much do you depend on alarm clocks to wake up every morning?

Table 4.1: Results obtained for Question 1

Dependency	Never	Low	Moderate	High	Always
Percentage (%)	3	4	9	34	50

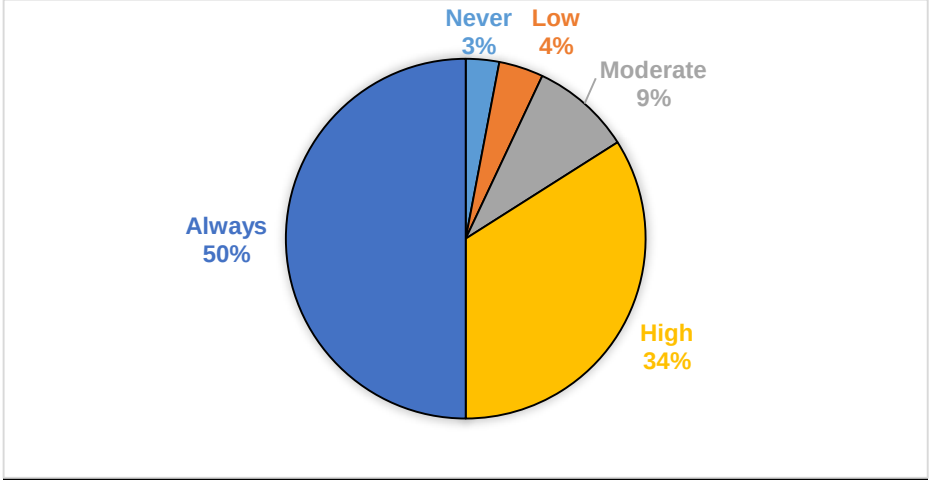


Figure 4.2: Analysis of results for Question 1

From the responses of Question 1, it can be seen that students are heavily reliant on alarm clocks to wake up in the morning. Half of the students answered that they always need an alarm clock in order to wake up while 34% rated their dependency on alarm

clocks as High. 4% and 9% of the students answered Low and Moderate respectively and only 3% do not rely on alarm clocks to wake up at all.

Question 2: Out of the 7 days in a week, on how many days do you use the snooze button?

Table 4.2: Results obtained for Question 2

Days	0	1	2	3	4	5	6	7
Percentage (%)	11	6	12	12	8	17	5	29

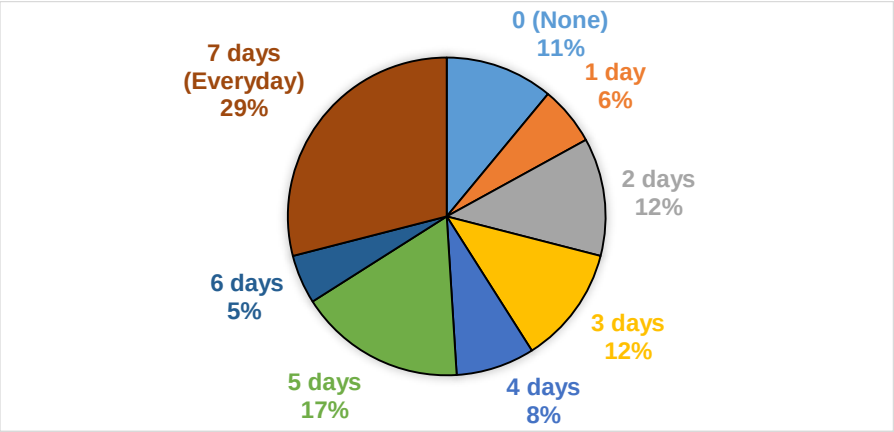


Figure 4.3: Analysis of results for Question 2

From the responses of Question 2, it can be seen that the snooze button is used by a majority of the students, with 29% of them using it every single day. Only 11% do not use the snooze button at all while 6%, 12%, 12%, 8%, 17% and 5% snooze their alarm clock on 1, 2, 3, 4, 5 and 6 days respectively.

Question 3: On average, how many times do you snooze your clock before waking?

Table 4.3: Results obtained for Question 3

Times	1	2-4	5-7	8-10	>10
Percentage (%)	27	62	6	2	3

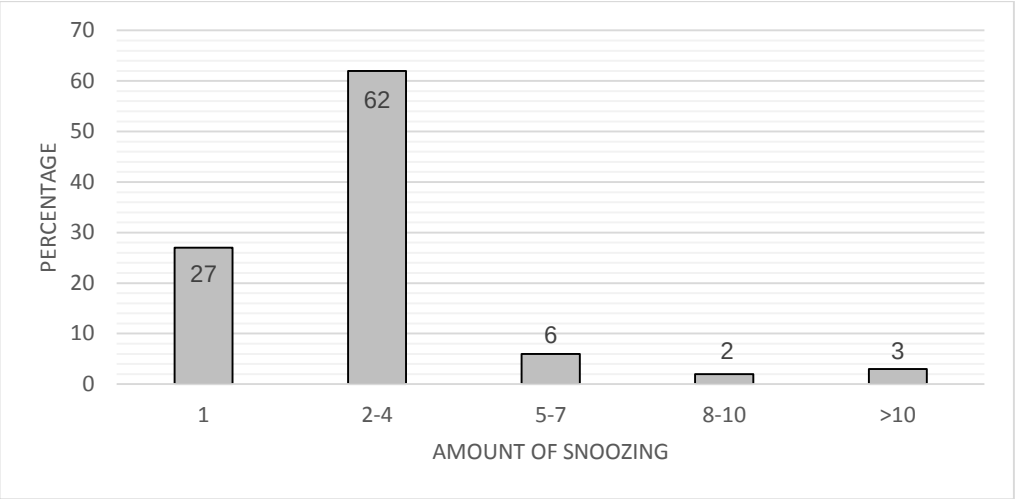


Figure 4.4: Analysis of results for Question 3

From the responses of Question 3, it can be seen that 62% of the students snooze their alarm clock 2 to 4 times before waking up. 27% of them only snooze the alarm clock once while another 6%, 2% and 3% snooze for 5 to 7 times, 8 to 10 times and more than 10 times respectively. Excessive snoozing raises a concern as snoozing causes sleep fragmentation which will lead to health problems as stated by Bonnet & Arand (2003).

Question 4: On average, how much does your actual waking time deviate from your initial alarm time?

Table 4.4: Results obtained for Question 4

Deviation (minutes)	<15	15-30	30-45	45-60	>60
Percentage (%)	28	39	24	7	2

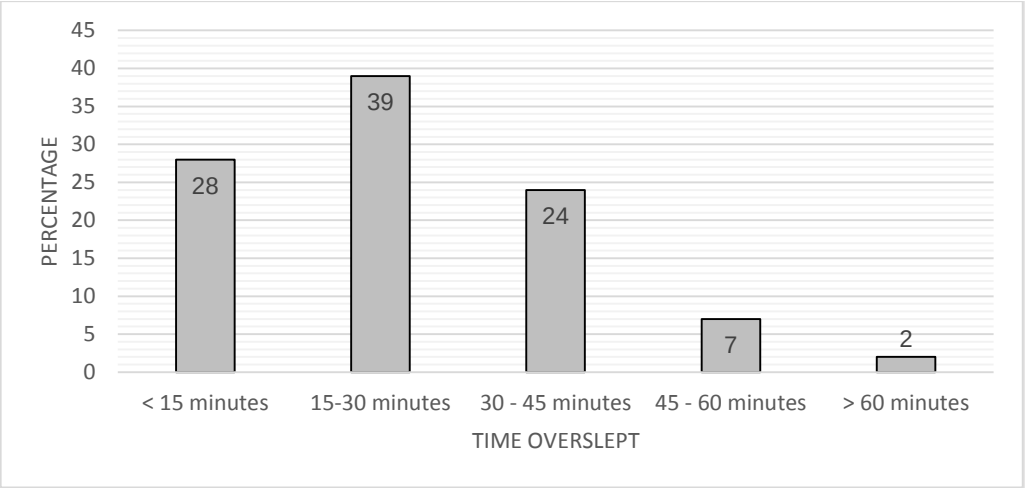


Figure 4.5: Analysis of results for Question 4

From the responses of Question 4, it can be seen that a majority, 39% of students waste between 15 to 30 minutes when they oversleep. 28% waste less than 15 minutes, 24% waste between 30 to 45 minutes, 7% between 45 to 60 minutes and only 2% waste more than an hour to oversleeping. This is also a concern as the time can otherwise be used for other more beneficial reasons.

Question 5: Have you ever overslept and entered late to lectures or classes?

Table 4.5: Results obtained for Question 5

Answer	Yes	No
Percentage	98	2

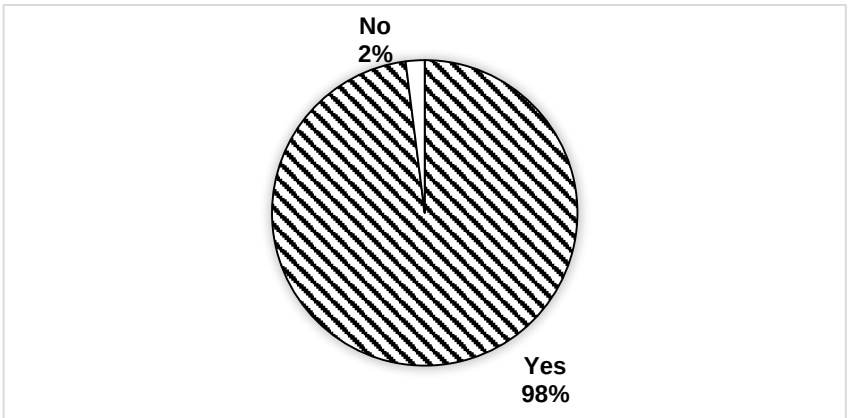


Figure 4.6: Analysis of results for Question 5

From the responses of Question 5, it can be seen that almost all students have been late to class due to oversleeping. 98% agreed that they have done so while only 2% claims that they have not been late as a result of oversleeping before. This shows that oversleeping is a serious problem that must be handled as entering classes late could impact their understanding in a particular subject matter.

Question 6: Have you ever overslept and missed any lectures or classes?

Table 4.6: Results obtained for Question 6

Answer	Yes	No
Percentage	73	27

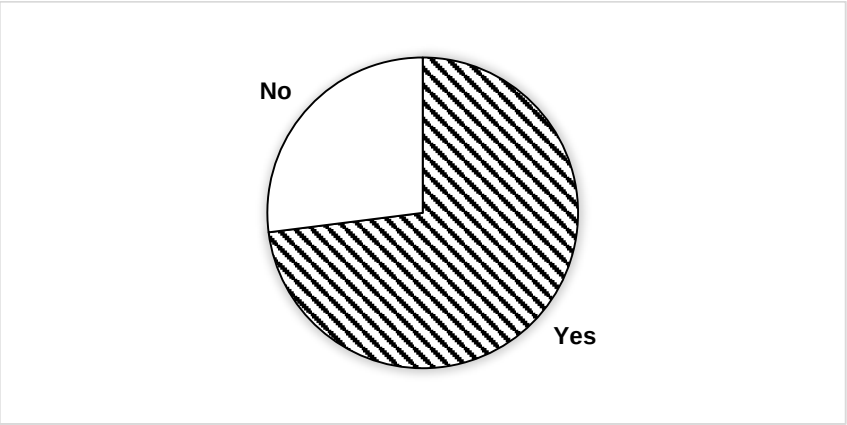


Figure 4.7: Analysis of results for Question 6

From the responses of Question 6, it can be seen it is also common for students to miss classes due to oversleeping. 73% answered that they have missed classes before while 27% have not. This shows that oversleeping is a serious problem as must be handled as missing classes would mean missing out important details which would eventually affect their performance.

Question 7: On average, how many classes do you miss in a week and a month as a result of oversleeping?

Table 4.7: Results obtained for Question 7

Answer	One week	One month
Average Value	1	3

From the responses of Question 7, it can be seen that on average, every student misses one class every week and three every month. In a semester of 4 months, this would mean a student will miss 12 classes due to oversleeping alone. Therefore, a solution to this problem must be identified to prevent it from continuing.

Question 8: Do you agree that conventional alarm clocks are not effective in waking the user up and making sure that the user stays awake after?

Table 4.8: Results obtained for Question 8

Answer	Yes	No
Percentage	79	21

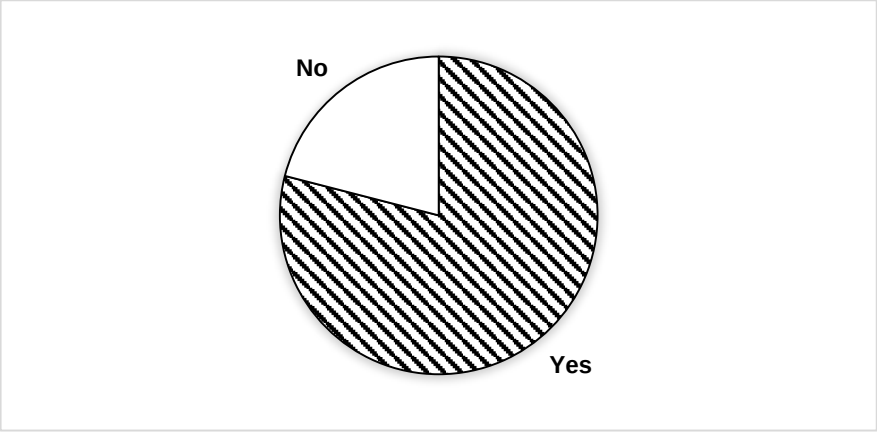


Figure 4.8: Analysis of results for Question 8

From the responses of Question 8, 79% of the students agrees that conventional alarm clocks are not any more effective in waking users up or making sure that they stay

awake while only 21% disagrees. This is probably due to their own experience in using conventional alarm clocks are not being able to wake up on their intended time. Therefore, there exists a need to create or develop a better alarm clock that would replace these conventional alarm clocks.

Question 9: From experience, do you agree that when the conventional alarm clock rings, users would sometimes go back to sleep after turning it off, and this almost feels like a sub-conscious decision?

Table 4.9: Results obtained for Question 9

Answer	Yes	No
Percentage	82	18

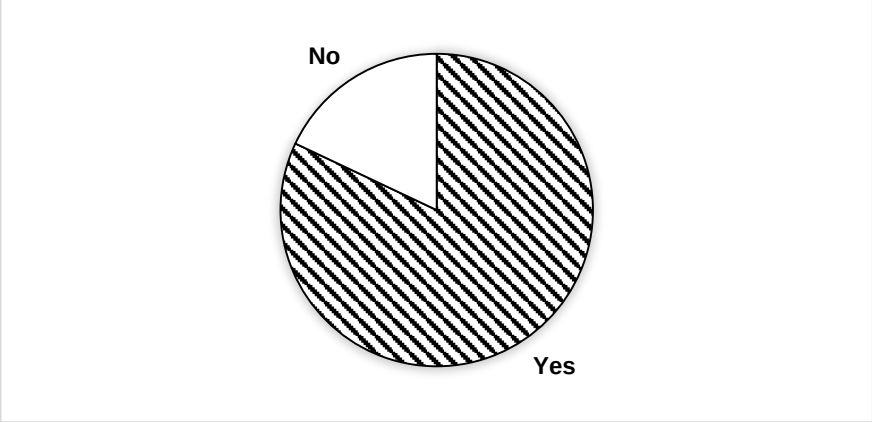


Figure 4.9: Analysis of results for Question 9

From the responses of Question 9, it can be seen that 82% of the students agree that conventional alarm clocks are not effective in keeping the user awake after waking him/her up while only 18% disagrees. When the alarm rings, the user would just turn it off and go back to sleep immediately and end up oversleeping.

Question 10: Do you agree that alarm clocks that are within the reach of users can be effortlessly turned off and therefore, not effective in waking them up?

Table 4.10: Results obtained for Question 10

Answer	Yes	No
Percentage	94	6

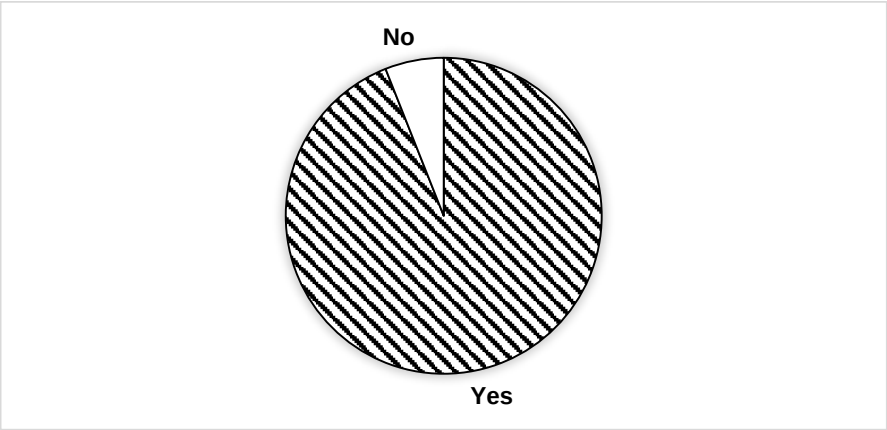


Figure 4.10: Analysis of results for Question 10

From the responses of Question 10, 94% of the students surveyed agrees that alarm clocks that are stationary and within reach are not effective as they can often be turned off easily. This means that they are less effective in waking the user up or to increase their alertness.

Question 11: How do you usually feel right after waking up in the morning after snoozing the alarm clock as compared to if you did not use the snooze button?

Table 4.11: Results obtained for Question 11

Answer	I feel sleepier and more tired.	I feel the same.	I feel more refreshed.
Percentage	61	27	2

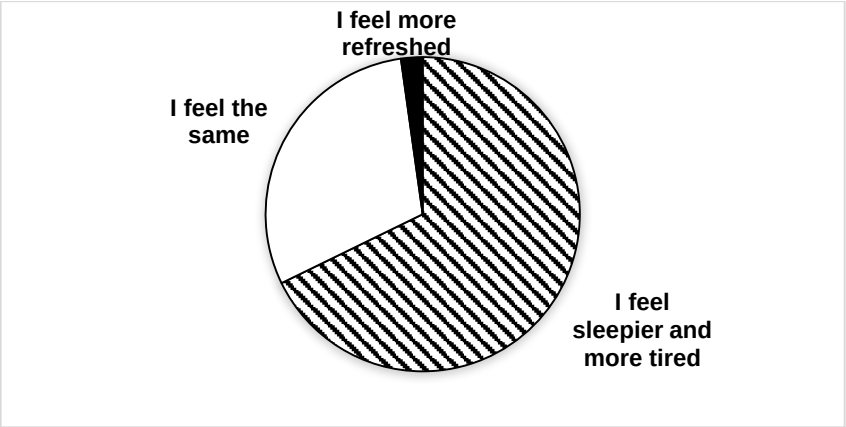


Figure 4.11: Analysis of results for Question 11

From the responses of Question 11, it can be seen that 61% of frequent snoozers agree that they feel more groggy and tired after waking up, 27% feel no difference and 2% claim that they feel better after doing so. This supports Stepanski (2002)'s statement that sleep fragmentation increases objective sleepiness upon waking up.

Question 12: What are your thoughts on having a smart, robotic alarm clock that will try to hide away from you under low objects in the room and forces you to find it in order to turn off the alarm?

Table 4.12: Results obtained for Question 12

Answer	Positive	Negative
Percentage	97	3

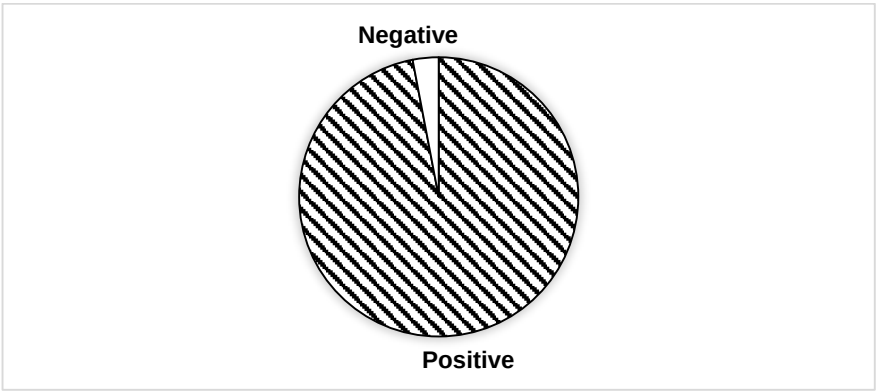


Figure 4.12: Analysis of results for Question 12

From the responses of Question 12, it can be seen that almost all, 97% of the students are supportive of BEDRUNN3R, a smart moving alarm clock that will force the user up to look for it. Only 3% of the students are hesitant are prefer to use their old alarm clocks. This shows that BEDRUNN3R has a high commercial potential among the target user group.

Question 13: If this moving alarm clock were to be sold, are you willing to pay between RM75 to RM100 for it?

Table 4.13: Results obtained for Question 13

Answer	Yes	No	Maybe
Percentage	65	22	13

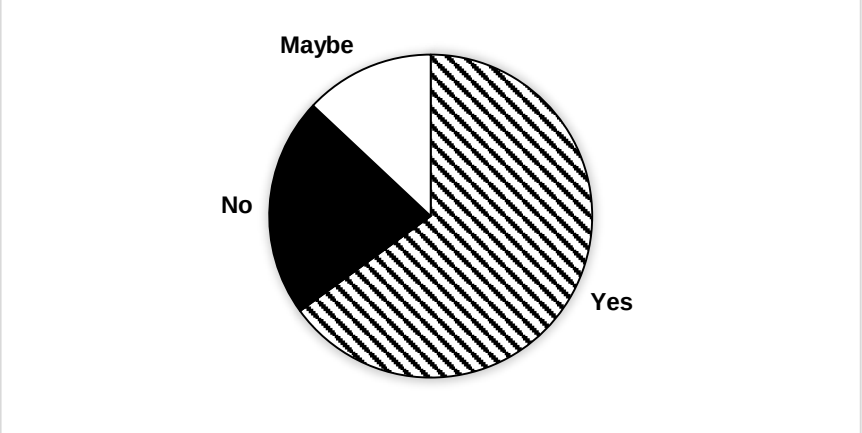


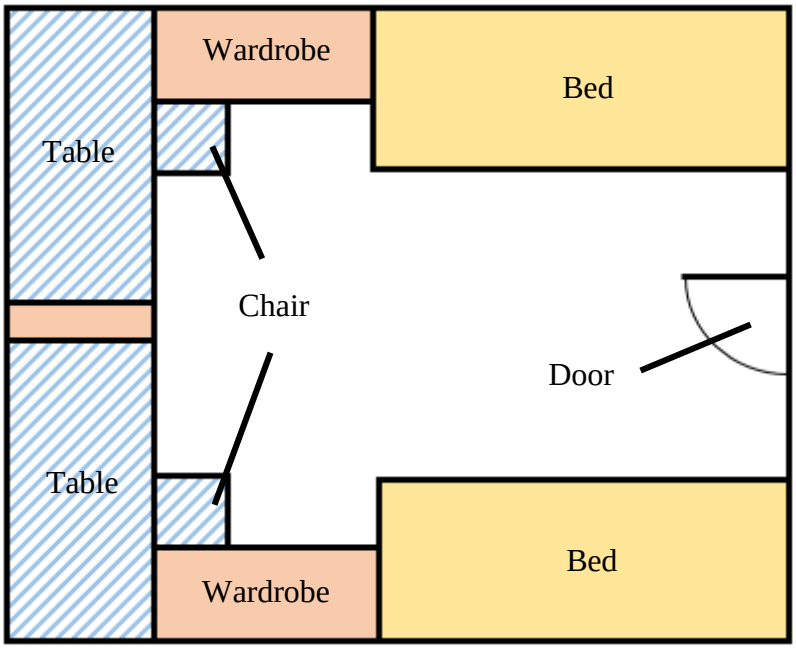
Figure 4.13: Analysis of results for Question 13

From the responses of Question 13, we can see that 65% of the students are willing to spend up to RM100 to purchase BEDRUNN3R after it is developed, and only 22% strongly say they would not. The estimated cost of BEDRUNN3R, if developed using Arduino would be less than RM100. This question also serves to survey its commercial potential for the target user group.

4.2 Observation

Observation was done on student bedrooms within Universiti Teknologi PETRONAS (UTP) and Multimedia University (MMU). The rooms that were observed were from different residential areas and include both male and female bedrooms. The reason for doing this is to have a clearer understanding and insight of the actual environment where the robot will be used in. Among the main points of focus are the size of the room, arrangement of tables, chairs, beds, wardrobes, type of material used for the floor and also common small objects found in the bedroom. Sketches of the room were taken and the information obtained were used to determine the best suitable rule-based algorithm to be implemented in the robot, in order to improve the chances of hiding.

From the observation made, the four most common student bedroom architectures are identified and shown here.



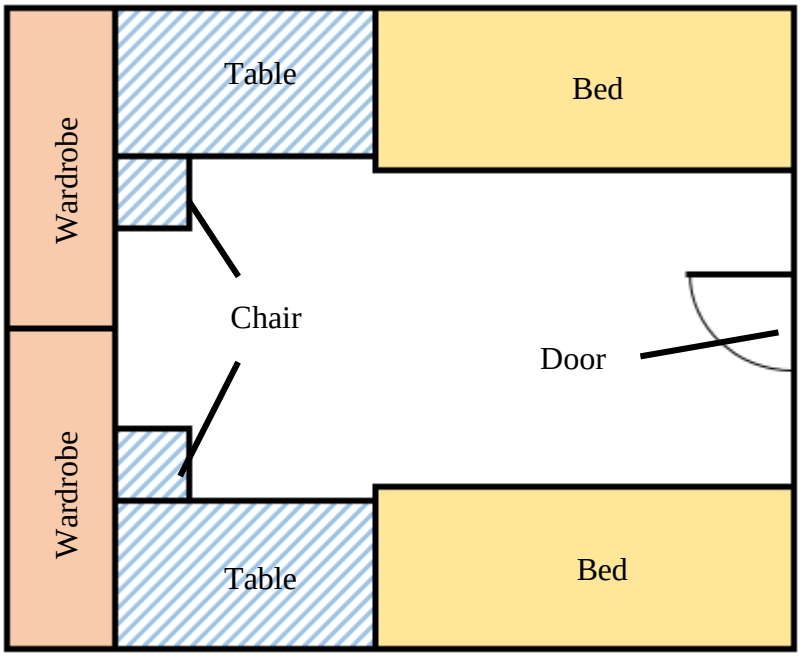
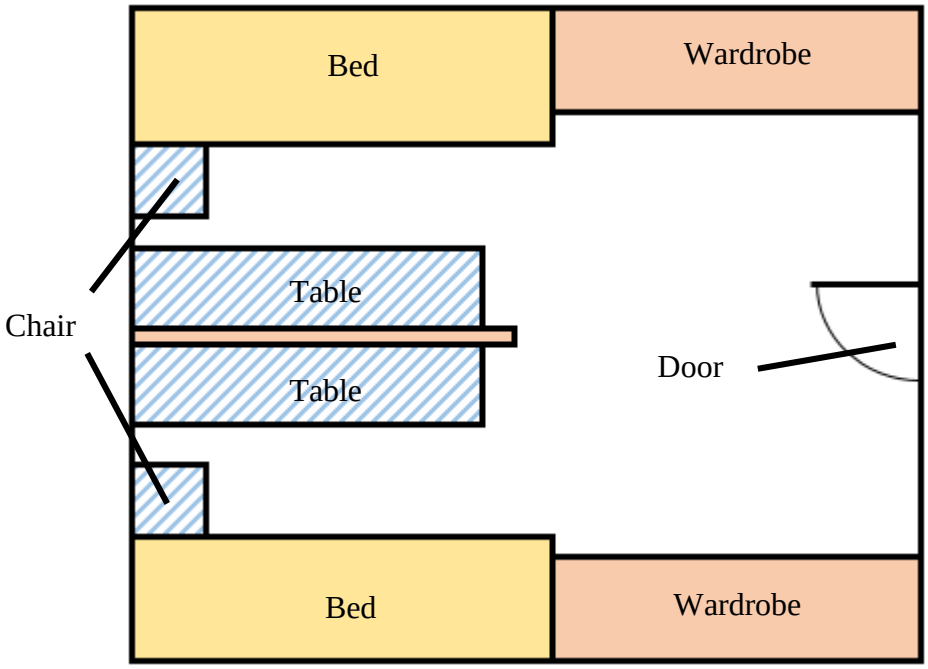


Table
Bed
Wardrobe
Chair
Door
Wardrobe
Table
Bed


Bed
Wardrobe
Table
Chair
Door
Table
Bed
Wardrobe

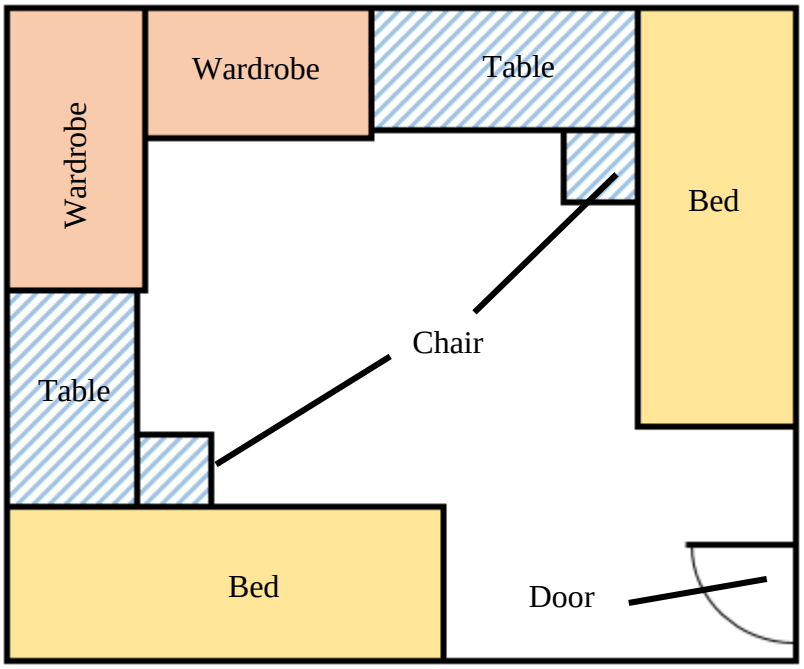


Figure 4.14: Common architecture of student rooms

From all of the four room architectures shown above, there are several common characteristics that are identified. These characteristics would then serve as the requirements and scope of the project. The tabulated requirements are shown below.

Table 4.14: Features of items that are observed during the observation.

Item	Observed Features
Room	The room architectures are either square or rectangular, with sharp 90° corners.
Size	The average dimension of rooms in UTP is 5m x 5m while the average dimension of rooms in MMU is 7m x 6m.
Table	The tables are located along the walls in the room, and often beside large objects such as wardrobes and beds.
Floor material	The material used for the floor is either cement, tile or carpet.
Obstacles	Common obstacles in a student's room include shoes, cups, bottles and small tins.

4.3 Prototype Design

Through the RAD model, several prototypes of BEDRUNN3R have been developed. After every stage of prototyping, the prototype is enhanced and improved in order to fulfill its requirements in the most efficient and effective way. The improvements are made not only to the hardware, but to the software as well. The prototypes of BEDRUNN3R are shown here.

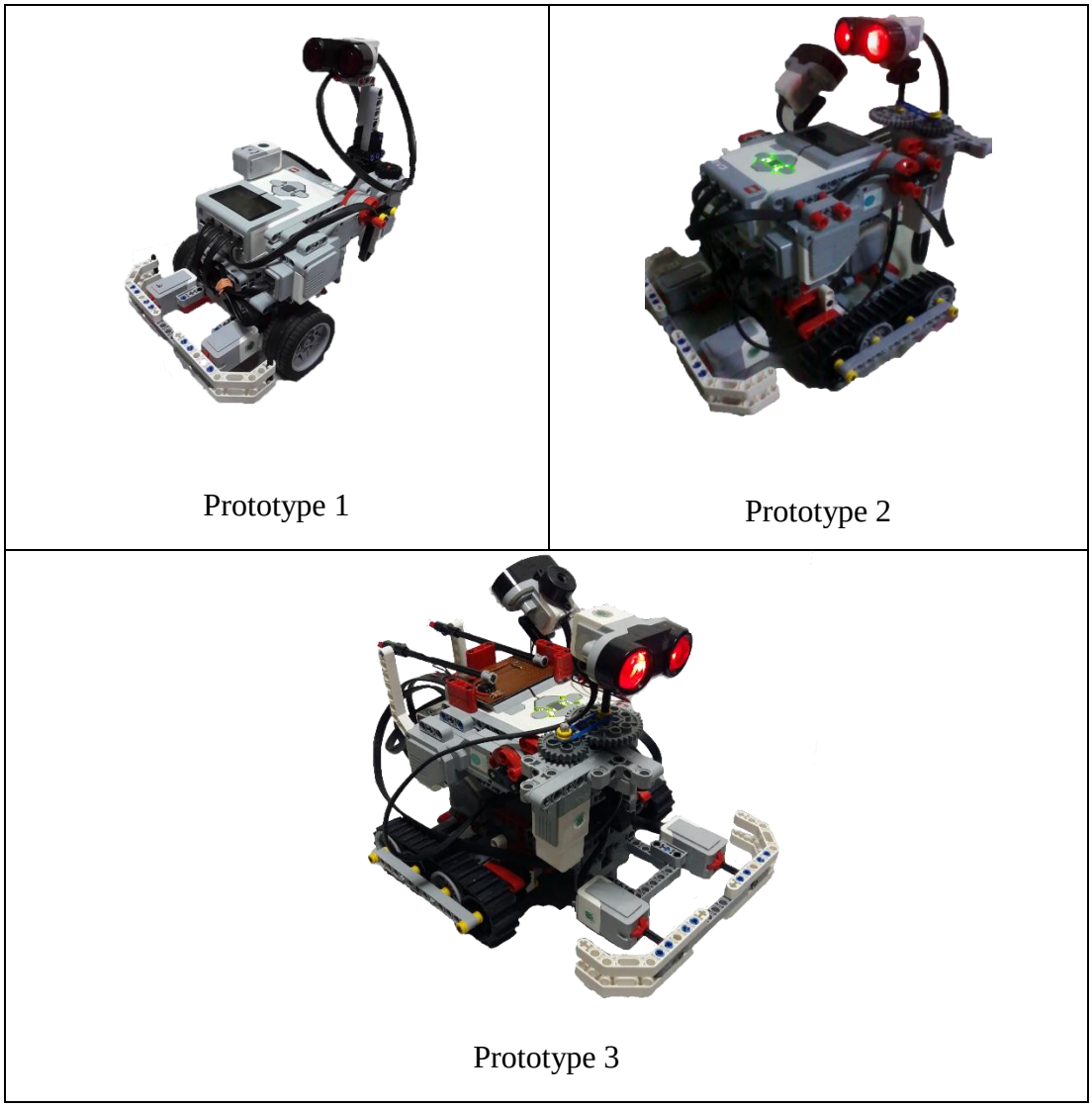


Figure 4.15: BEDRUNN3R prototypes

The improvements made to each prototype are discussed in the next table.

Table 4.15: Advantages and disadvantages of each prototype

Prototype	Advantages	Disadvantages
1	• Gyro sensor allows for accurate rotation of robot. • Smaller frame and design.	• Only able to move on smooth surface. • Ultrasonic sensor is unable to differentiate between user and wall. • The gear may run out of its tracks.
2	• Tank wheels enable movement on all forms of surface. • Infrared sensor enables detection of user. • Gears enable the robot to go to very high speed.	• The infrared sensor is obstructed by the ultrasonic sensor. • The ultrasonic sensor has low effectiveness in identifying low objects. • The robot is too high. • Turning might be less accurate due to the absence of gyro sensor.
3	• Tank wheels enable movement on all forms of surface. • The robot is lower. • Infrared sensor is not obstructed by other parts of the robot. • Ultrasonic sensor has a higher effectiveness. • Gears enable the robot to go to very high speed. • Higher robustness. • Higher volume with the added piezo buzzers.	• Bigger frame and design. • Turning might be less accurate due to the absence of gyro sensor.

Based on the table above, the latest prototype, Prototype 3 has successfully improved the flaws and disadvantages of the prototypes prior to it. Although there are still some disadvantages, these disadvantages do not pose any impact or risk on the main functionalities of BEDRUNN3R. Prototype 3 has successfully implemented the use of infrared sensors in Running Mode, enabling it to detect users and differentiating them from other obstacles that may be present in the room.

Besides, the use of tank wheels has enabled it to move on all sorts of surface in the room, including carpets and uneven surfaces. By having a higher stability and a lower

design, this ensures that it is more robust and will not get damaged easily while moving around the room. The parts of Prototype 3 of BEDRUNN3R are labelled in Figure 4.16.

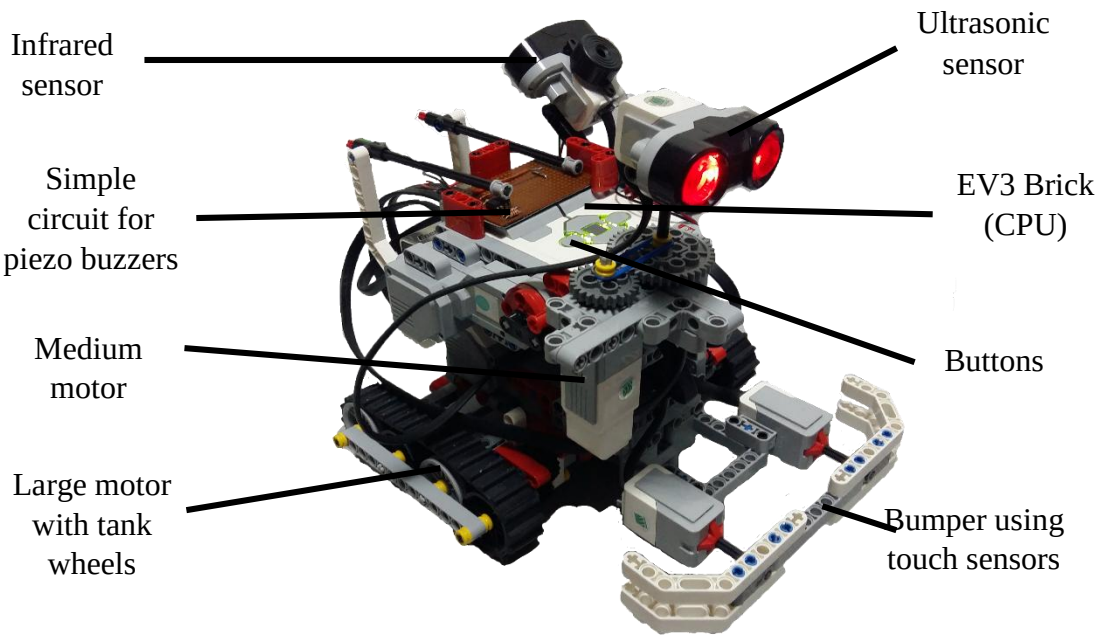


Figure 4.16: Detailed view of BEDRUNN3R

4.4 Performance Tests

In this phase, the performance of the prototype is tested to ensure that the prototype is able to perform its intended functionalities at an optimum level. The tests that have been performed are Obstacle Avoidance Test, Surface Movement Test and Hiding Test. Useful modifications and additional features can be further revised onto the prototype after the performance of the prototype has been monitored. The results of the tests carried out will be discussed in the section below.

4.4.1 Obstacle Avoidance Test

The obstacle avoidance feature is studied to ensure that BEDRUNN3R can move across the room with minimal obstruction of the physical environment. For this test, the touch and ultrasonic sensors are tested. The test is conducted within an actual room,

with an obstacle the size of a cup and weighing 300 grams. The testing compound is shown in Figure 4.17.

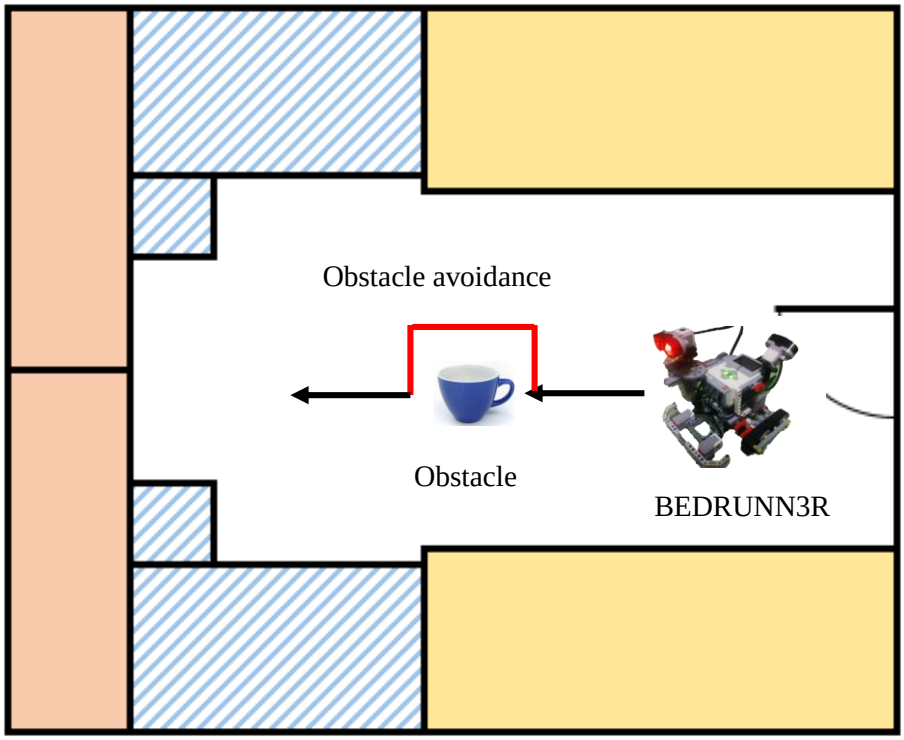


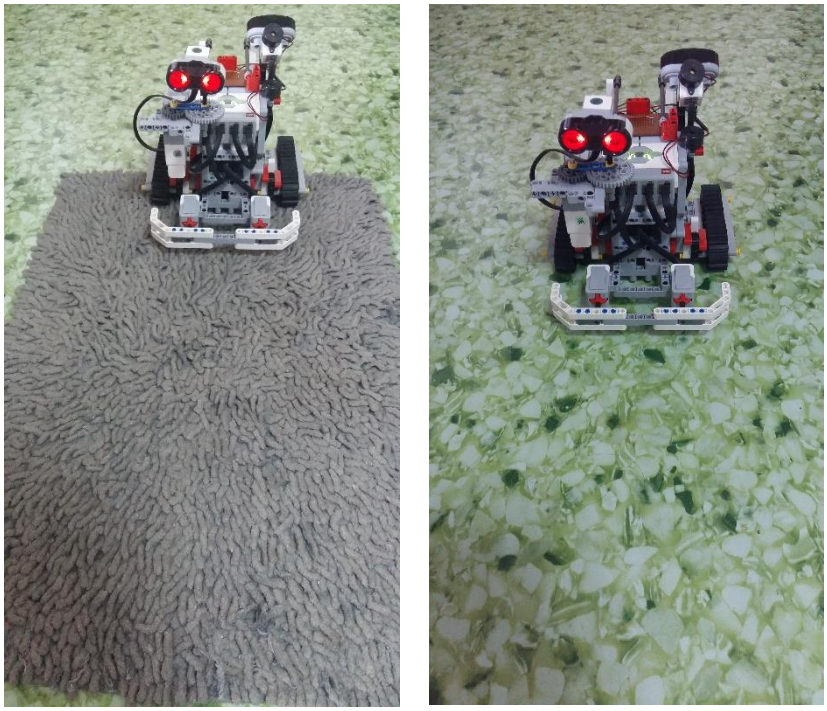
Figure 4.17: Obstacle Avoidance Test

The test results show that BEDRUNN3R is able to avoid small obstacles that are detected via its frontal touch sensors. It is able to move in a certain programmed way that allows it to return to its original path after avoiding the obstacle in its way. However, due to the constraints that have been defined at the start of this project, BEDRUNN3R is currently only limited to obstacles not bigger than the size of a regular cup.

4.4.2 Surface Movement Test

Next, Surface Movement Test is carried out to test the movement of the prototype on different surfaces which are commonly found in student rooms. A carpet is used as the rough surface while a cement floor is used as the smooth surface. This test tests for the speed of the prototype on these surfaces as well as whether it is able to move smoothly on the surfaces. The speed is calculated using the formula shown.

$$Speed\ (v) = \frac{\text{Distance (d)}}{\text{Time (t)}}$$



Rough surface testing Smooth surface testing

Figure 4.18: Surface Movement Test

Table 4.16: Results of Surface Movement Test

Surface	Distance (m)	Time (s)	Speed (ms^{-1})	Able to Move
Rough	1	3.3	0.303	Yes
Smooth	1	3.1	0.323	Yes

The results of the surface movement test show that BEDRUNN3R is able to move on both rough or uneven surfaces and also smooth surfaces. The speed of movement differs by a small amount of 0.02 ms^{-1} on both surfaces, with BEDRUNN3R being faster when the surface is smooth. This small difference however would not affect the performance of BEDRUNN3R in the actual room as ample time of 2 minutes is allocated for it to move around.

4.4.3 Hiding Test

The Hiding Test aims to test one of the main function of BEDRUNN3R, which is to look for places to hide in the bedroom. A successful hide would mean that the prototype has, with the use of both its touch and ultrasonic sensors, managed to locate a place which fulfills the pre-programed criteria of a low object. For this test, a time limit of 2 minutes is given for the robot to move around the test room and the test is stopped the moment the time is up. The time needed for a successful hide is not recorded as it is not essential in determining the performance of the robot, as it is understood that different rooms have different layouts and object settings. The results of the Hiding Test are tabulated.

Table 4.17: Results of Hiding Test

Test Case	Successful	Not Successful
1	✓	
2	✓	
3	✓	
4		✓
5	✓	
6	✓	
7		✓
8	✓	
9	✓	
10	✓	
11	✓	
12	✓	
13	✓	
14		✓
15	✓	
16		✓
17	✓	
18	✓	
19		✓
20	✓	
21	✓	
22	✓	
23		✓

24		✓
25	✓	
26	✓	
27		✓
28	✓	
29	✓	
30	✓	
TOTAL	**22**	**8**

From the results, it can be seen that BEDRUNN3R has managed to hide itself in 22 out of 30 test cases. This translates to a 73.3% success rate of finding a hiding place in room before the alarm is sounded. This would mean that the user would have to search for the alarm clock out of all possible spots in the room. For the cases in which it does not manage to hide, the Running Mode will be triggered to force the user to put in a little more effort to catch it. Some possible reasons for it not being able to locate a hiding spot is that it does not search in every single corner of the room, but instead follows a rule-based algorithm to optimize its search. It may also happen in rooms where many large obstacles are clustered together at the same spot.

4.5 User Acceptance Test

The User Acceptance Test (UAT) or the field testing of BEDRUNN3R was conducted starting from the 25th of June 2015. This testing was carried out in the actual bedroom environments of respondent groups consisting of all heavy sleepers. The respondents are selected and divided into 4 groups of different genders and age groups. The rationale and purpose behind the selection of respondents is because males and females have different sleeping patterns and individuals that have experienced their internship would also have different sleep habits. By having these different groups, it helps to diversify the results obtained in order to get a more accurate result that is more applicable to the real world. The details of the respondents are shown in Table 4.5.

Table 4.18: Details of UAT Respondents

Respondent Groups	Gender	Age Group
A	Male	Before Internship

B	Male	After Internship
C	Female	Before Internship
D	Female	After Internship

Since this testing will not be monitored by me, but by each respondent in their respective rooms due to the long testing hours and university policies. Thus, each respondent was first briefed on the functions of BEDRUNN3R, how to operate it and also how to set up their room to ensure that nothing goes wrong during the testing process. The steps were simple, the respondents would have to switch BEDRUNN3R on right before they sleep, and set the alarm based on the number of hours they would like to sleep. Then, the small circuit board would have to be placed in its holder and BEDRUNN3R on the floor to face any random direction. Once they have been woken up by the alarm, they would have to record the time taken to turn off the alarm and whether they chose to snooze the alarm or go back to sleep. The results of this test will be shown and discussed.

Table 4.19: Results of UAT Using BEDRUNN3R

Group	Test Case	Alarm Snoozed		Waking Time		Time Taken to Turn Alarm Off (s)
		Yes	No	On Time	Overslept	
A	1		✓	✓		41
	2		✓	✓		37
	3		✓	✓		58
B	1		✓	✓		43
	2		✓	✓		45
	3		✓		✓	51
C	1		✓	✓		58
	2	✓			✓	34
	3		✓	✓		39
D	1		✓	✓		55
	2		✓	✓		29
	3		✓	✓		45

The same respondents are then tested using conventional alarm clocks to wake them up instead of BEDRUNN3R. This test is conducted to prove or show the declining effectiveness of conventional alarm clocks and to compare the effectiveness of

BEDRUNN3R against these alarm clocks. For this test, the same number of test cases is used and the respondents would have to record the results in a separate table.

Table 4.20: Results of UAT Using Conventional Alarm Clocks

Group	Test Case	Alarm Snoozed		Waking Time		Time Taken to Turn Alarm Off (s)
		Yes	No	On Time	Overslept	
A	1		✓		✓	8
	2	✓			✓	5
	3		✓	✓		5
B	1	✓			✓	9
	2	✓			✓	7
	3	✓			✓	14
C	1	✓			✓	5
	2	✓			✓	6
	3		✓		✓	8
D	1		✓	✓		12
	2	✓			✓	9
	3	✓			✓	6

The results of the tests conducted are then further evaluated to compare the effectiveness of BEDRUNN3R against conventional alarm clocks.

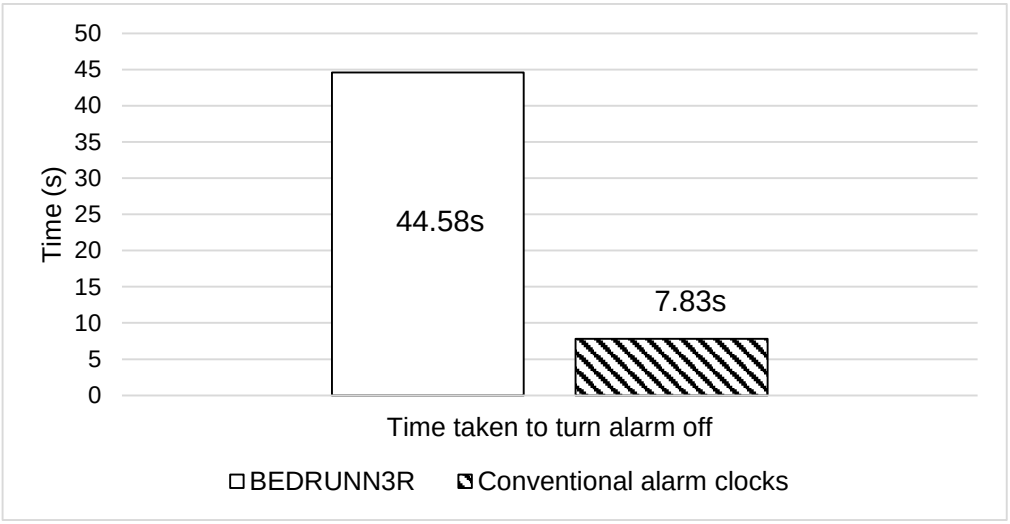
Table 4.21: Evaluated Result of UAT Using BEDRUNN3R

Group	% of Snoozing	% of Oversleeping	Average Time Taken to Turn Alarm Off (s)
A	0	0	45.33
B	0	33.33	46.33
C	33.33	33.33	43.67
D	0	0	43
TOTAL	**8.33**	**16.67**	**44.58**

Table 4.22: Evaluated Result of UAT Using Conventional Alarm Clocks

Group	% of Snoozing	% of Oversleeping	Average Time Taken to Turn Alarm Off (s)
A	33.33	66.67	6
B	100	100	10

C	66.67	100	6.33
D	66.67	66.67	9
TOTAL	**66.67**	**83.33**	**7.83**



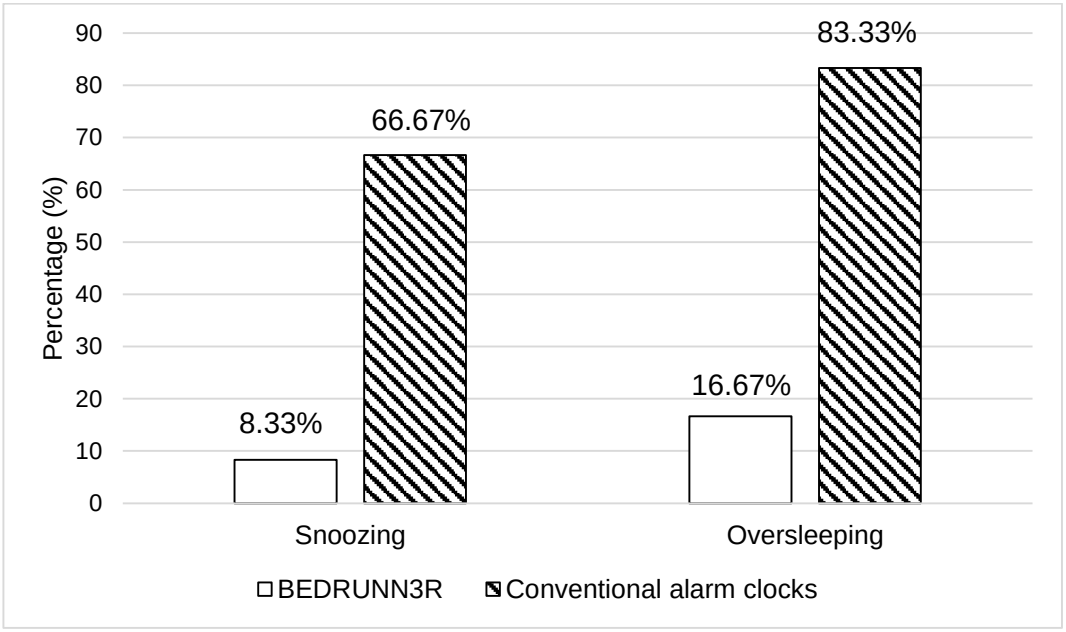


Figure 4.19: Graphs showing the comparison of test results

From the tables and figure above, we can see that the percentage of snoozing using BEDRUNN3R has been greatly reduced by 58.34%, from 66.67% to 8.33% of conventional alarm clocks and BEDRUNN3R respectively. The percentage of oversleeping has also been reduced from 83.33% to a mere 16.67%, indicating a

successful reduction of 66.66%. For the average time taken to turn alarm off, BEDRUNN3R has proven successful in making it hard for the users to turn it off, with an average time of 44.58 seconds as compared to the conventional alarm clock with a 7.83 seconds. That means that on average, users will need an extra 36.75 seconds to move around the room before they manage to turn off the alarm.

This result shows that by forcing users to spend a longer time in turning off the alarm clock, the users will have to move around more, increasing their level of alertness. The users are also forced to think of the possible hiding spots where BEDRUNN3R could be hiding, and this combined with the increased movement could possibly contribute to the increased awareness and reduced sleepiness. Thus, users have a lesser tendency to go back to sleep which would lead to oversleeping, and they are less likely to snooze their alarm clock. Thus, BEDRUNN3R has successfully exhibited that the application of Artificial Intelligence in alarm clocks will make it harder for users to turn them off, increase the probability of the user waking up on time and reduce the frequency of use of the snooze button.

Although the target users for BEDRUNN3R are for all age groups, the testing was done on only students. The justifications behind this are because students have the most irregular sleeping patterns amongst other age groups, as discussed in the literature and also from the results of the survey done. Therefore, they have a higher dependency on alarm clocks as a daily companion and will exhibit a clearer difference in their waking patterns through the introduction of BEDRUNN3R. By also focusing on younger groups, it is easy to instill a proper sleeping and waking habit into their minds as they are still able to adapt to new ways.

CHAPTER 5
CONCLUSION AND RECOMMENDATIONS

5.0 Conclusion

It is undeniable that alarm clocks have done a good job in serving their purpose to mankind ever since their inception and it is difficult to imagine our life without one. However, as people starts to get used to the same routine every morning, the effectiveness of the conventional alarm clocks are slowly plummeting, rate of oversleeping is increasing and this is a major concern because alarm clocks are a major part of almost everybody's lives. The invention of the snooze button, although hailed as a gift to most people, is actually a threat in disguise and if overused, will lead to adverse effects to the body. Therefore, the need to improve these alarm clocks must not be overlooked and Artificial Intelligence may just prove to hold all the answer to this problem. It is also based on this theory that this project, BEDRUNN3R was conceptualized and developed as a Final Year Project.

Throughout the duration of Final Year Project I and II, all of the objectives have been successfully met. They will be discussed in more details below.

> *Objective 1: To study the problems associated with sleep that are often faced by people.*

The first objective has been successfully met following the study of literatures related to the topics of sleep, sleep-related health problems, and also through the survey carried out among 100 students of Universiti Teknologi PETRONAS.

Objective 2: To conduct a comparative study on existing moving alarm clocks in the market that functions using movement.

The second objective has also been successfully met, following the comprehensive study of all the current existing moving alarm clocks in the market that uses movement. BEDRUNN3R is compared with Clocky, Tocky, Puzzle Alarm Clock, Rocket Launcher Alarm Clock and also the Flying Alarm Clock.

Objective 3: To develop an intelligent moving alarm clock that implements the application of artificial intelligence to solve the problems studied in (1) and (2).

The third objective has also been met, with the development of Prototype 3 for BEDRUNN3R that follows a rule-based algorithm and is intelligent enough to navigate itself around the room to look for a place to hide whilst avoiding obstacles. BEDRUNN3R is also equipped with intelligence to detect the presence of users and to move itself away from the user.

Objective 4: To test the prototype against the usage of traditional and conventional alarm clocks.

The fourth objective, the testing phase, has been achieved with the successful testing of BEDRUNN3R on 4 respondents from Universiti Teknologi PETRONAS who are all heavy sleepers. The testing includes testing in the test environment as well as the actual bedroom environment. The results of testing proved that BEDRUNN3R has successfully reduced the rate of oversleeping and snoozing, as well as increased the difficulty to turn the alarm off, as represented by time taken to turn off the alarm.

5.1 Recommendations

As stated in the scope of studies, the development of the prototype is limited to only LEGO Mindstorms EV3 as there is a strict time constraint to this project. In the future, I would recommend for the real product to be developed using Arduino, while

following the same hardware and software configurations that have been identified and developed in this project. The main reason for this is as the parts and sensors for Arduino are cheaper and cost lesser to be developed in a large scale. Arduino will also allow the size of the alarm clock to be smaller and at the same time, weights lesser in comparison to LEGO.

Besides that, I would recommend for Radio Frequency Identification (RFID) to be used to replace Infrared Sensor (IR) in the final product. This is because RFID has a larger range for detection and has a coverage of 360° while IR requires a clear line of sight to function. The reason why RFID was not used in this project is because RFID is not compatible with LEGO Mindstorms EV3 and therefore, IR was instead used to simulate the functions of the proposed RFID.

REFERENCES

Bonnet, N. H. & Arand, D. L. (2003). *Clinical effects of sleep fragmentation versus sleep deprivation*. Sleep Medicine Reviews, Vol. 7, No. 4, pp. 297-310, 2003.

Bruck, D. & Pisani, D. (1998). *The effects of sleep inertia on decision-making performance.* J. Sleep Res. (1999) 8, 95-103.

CentreForSoundSleep (n.d.). *The science of sleeping*. Retrieved March 20, 2015 from http://www.centerforsoundsleep.com/sleep-disorders/stages-of-sleep/

Cheung, M. M. (2003). *Sleep patterns of secondary school children in Hong Kong, a cross-sectional study.* The University of Hong Kong, 2003.

Davies, R. J., Belt, P.J., Roberts, S.J., et al. (1993). *Arterial blood pressure responses to graded transient arousal from sleep in normal humans*. J Appl Physiol 1993; 74: 1123-1130.

Jewett, M. E., Wyatt, J. K. & Cecco, A. R. (1998). *Time course of sleep inertia dissipation in human performance and alertness.* J. Sleep Res (1999) 8, 1-8.

Jones, M. T. (2008). *Artificial intelligence: a systems approach*. Jones & Bartlett Learning.

McCoy, J. G. & Strecker, R. E. (2011). *The cognitive cost of sleep lost*. Neurobiol Learn Mem. 2011 November; 96(4): 564–582. doi:10.1016/j.nlm.2011.

McKibben, S. (2014). *Wake up call.* Retrieved March 21, 2015 from http://www.ascd.org/publications/newsletters/education_update/apr14/vol56/num04/Wake-Up_Call.aspx

Morell, M. J. & Finn, L. (2000). *Sleep fragmentation, awake blood pressure, and sleep-disordered breathing in a population-based study*. Am J Respir Crit Care Med Vol 162. pp 2091–2096, 2000.

Russel, S. & Norvig, P. (2013). *Artificial Intelligence: A Modern Approach (3rd ed.)*. Prentice Hall.

Sleepdex (n.d.) *Stages of sleep*. Retrieved March 21, 2015 from http://www.sleepdex.org/stages.htm

SleepFoundation (n.d.). *Teens and sleep*. Retrieved March 21, 2015 from http://sleepfoundation.org/sleep-topics/teens-and-sleep

Sleepnet (n.d.). *Sleep terms, definition and abbreviations*. Retrieved March 20, 2015 from http://www.sleepnet.com/definition.html

StartSchoolLater (n.d.). *Wake up call (Fast Facts).* Retrieved March 21, 2015 from http://www.startschoollater.net/wake-up-calls-fast-facts.html

Stepanski, E. J. (2002). *The effect of sleep fragmentation of daytime function*. SLEEP, Vol. 25, No. 3, 2002.

Taras, H. & Datema, W. P. (2005). *Sleep and student performance at school*. Journal of School Health, September, 2005;75(7):248–254.

Travelodge (2007*). Oversleeping costs Britain £619m a year*. Retrieved March 21, 2015 from http://www.travelodge.co.uk/press_releases/press_release.php?id=239

APPENDICES

Appendix A

Exhibition and demonstration of BEDRUNN3R during the Formula 1 PETRONAS Malaysia Grand Prix Showcase

Appendix B

Exhibition of BEDRUNN3R along with some other projects at UTP's booth during Karnival Jom Masuk University in Ipoh.

Appendix C

BEDRUNN3R's booth during International Invention and Innovation Exhibition (ITEX) 2015.

Appendix D

BEDRUNN3R winning Silver Award at ITEX 2015.