Smart Office System

By

Nur Diyana Nadirah binti Shaharuddin
16332

Dissertation submitted in partial fulfillment of
the requirements for the
BACHELOR OF TECHNOLOGY (Hons.)
(BUSINESS INFORMATION SYSTEM)

Universiti Teknologi PETRONAS
Bandar Seri Iskandar
31650
Perak Darul Ridzuan

CERTIFICATE OF APPROVAL

Smart Office System

By

Nur Diyana Nadirah binti Shaharuddin
16332

A dissertation submitted to the
Business Information System Programme
Universiti Teknologi PETRONAS (UTP)
In partial fulfillment of the requirements for the
BACHELOR OF TECHNOLOGY (Hons.)
(BUSINESS INFORMATION SYSTEM)

Approved by:

_____

Dr. Noreen Izza Arshad
Supervisor,
Computer & Information Sciences Department
Universiti Teknologi Petronas

CERTIFICATE 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 reference and acknowledgement, and that the original work contained in this report have not been undertaken or done by unspecified sources or individuals.

_____

(NUR DIYANA NADIRAH BT SHAHARUDDIN)

ABSTRACT

Smart Office System is an office automation system developed to help small scale offices and workplaces in Malaysia to control their energy and electricity usage, leading to the decrease of global warming and carbon dioxide emission to the atmosphere. This prototype is developed using Raspberry Pi, a credit card sized computer that is cheap and easy to use, connected to sensors and screens, also combined with extensive programming work to complete the whole system. The current problem is that 93.81 percent of the energy industry in Malaysia relies on finite resources such as fossil fuels to generate power for electricity. Fossil fuels will be diminished very soon if it is not conserved and used with care. Other than that, excessive production of electricity will contribute to global warming and increase the carbon dioxide emission to the atmosphere. This project focuses on helping the small scale commercial buildings such as offices, showrooms and workplaces in Malaysia save energy for a brighter future of the environment. Smart Office System will be developed and created to be a low cost, easy-to-build, user-friendly automation system that will help numerous companies to decrease their overhead and facility costs that are usually used to pay off electricity usage. After diligently finishing the project, two testing sessions had been done to determine the usability and functionality of the product, and from the testing, it is found out that the product is majorly accepted and liked by the respondents, with a few remarks and comment on the product to further enhance and improve the product.

Table of Contents

CERTIFICATE OF APPROVAL ii

CERTIFICATE OF ORIGINALITY iii

ABSTRACT iv

LIST OF FIGURES viii

LIST OF TABLES viii

CHAPTER 1 1

INTRODUCTION 1

1.1 Background 1

1.2 Problem Statement 2

1.3 Objectives 3

1.4 Scope of Study 3

CHAPTER 2 4

LITERATURE REVIEW 4

2.1 The Importance of Having an Smart Office Building 4

2.2 Comparative Study on Sensors 5

2.1.1 Overview 5

2.1.2 Sensor Technology 6

2.1.3 Features 7

2.3 Comparative Study on the Existing System 11

3.1 The system 11

3.2 Features 14

2.4 Comparative Study on the Technology 17

3.1 Overview 17

3.2 Hardware 17

2.5 Gaps in the Literature and Way Forward 20

CHAPTER 3 21

METHODOLOGY/PROJECT WORK 21
3.1 Project Development Methodology 21
3.1.1 Analysis 22
3.1.2 Design 23
3.1.3 Coding 23
3.1.4 Testing 25
3.1.5 Close-out 25
3.2 Data Collection Approach 26
3.3 Gantt Chart & Key Milestone 27
3.4 Tools/Equipment to Be Used 28
3.4.1 Raspberry pi Model B+ 28
3.4.2 LCD Touch Screen Display 29
3.4.3 PIR Sensor 30
CHAPTER 4 31
RESULTS AND DISCUSSION 31
4.1 Interview results 31
4.2 SketchUp design 32
4.3 Completed prototype 33
4.4 GUI design 34
4.5 Finalized GUI Design 36
4.6 Source Code 38
CHAPTER 5 39
TESTING RESULT 39
5.1 Functionality testing 39
5.2 Usability Testing 41
CHAPTER 6 45
CONCLUSION AND RECOMMENDATION 45

6.1 Conclusion 45
6.2 Challenges faced during the project execution 46
6.3 Improvements 47
REFERENCES 48
Websites 48
Books 49
APPENDICES 50

LIST OF FIGURES

Figure 1: Passive Infrared (PIR) sensor working principle 5
Figure 2: Microwave sensor working principle 6
Figure 3: Comparison between sensors 7
Figure 4: Project methodology + SDLC 21
Figure 5: Raspberry Pi Model B+ 28
Figure 6: Floor Plan for office 32
Figure 7: Photo of completed prototype model 33
Figure 8: Log in interface to SOS 34
Figure 9: Home page 34
Figure 10: Switch Off confirmation page 35
Figure 11: First interface of Smart Office System 36
Figure 12: Manual mode interface of SOS 37
Figure 13: Summary of the functionality testing by respondents 40
Figure 14: Summary of the answers for Q1 to Q6 of the survey 43
Figure 15: Summary of Q7 to Q10 from the survey 44
Figure 16: Front door view of scale model 50
Figure 17: Reception area 50
Figure 18: Meeting room 51
Figure 19: Workplace & lounge area 51

LIST OF TABLES

Table 1: Comparison of the systems 11
Table 2: Comparison on the features 14
Table 3: Specification for Arduino Uno vs. Raspberry Pi Model B (Orshini, 2014) 17

CHAPTER 1

INTRODUCTION

This chapter covers about the overall of the project. It explains in detail about the background of this project, problem statement, objectives of this project and also the specific scope of study of the author.

1.1 Background

Today, there are a lot of smart office systems in the market that are sold to help us conserve and save electricity using automated systems that controls the electricity usage and to decrease vampire power. Vampire power, or standby power refers to the electric power consumed by electronic and electrical appliances while they are switched off (but are designed to draw some power) or in a standby mode, such as the computers, desktops, coffee machine and photocopy machine in the office. Some of these systems that are available in the market include Vyrox and SmartHome. No matter what type of system they use, they are all to promote energy saving, thus leading to decrease wastage of finite energy sources such as fossil fuel to produce electricity. However, these choices are not very popular in Malaysia because it is very pricey and expensive, due to the lack of competitors in their industry. Other than that, Malaysians are also lacking the awareness to save and conserve energy as they are not well-versed of the consequences and effects of electricity wastage on the environment.

As such, this project will develop a low cost, user-friendly and easy to make prototype system using a credit card sized computer called Raspberry Pi as the main processor and sensors to control and help conserve energy in small scale offices and workplaces. By doing this, I predicted that the system will be easier to be implement and much more cheap for the small companies to buy and implement them in their working environment.

1.2 Problem Statement

According to the Ministry of Energy, Green Technology and Water (KETTHA), peak demand for electricity in Peninsular Malaysia reached 15,476 Megawatts in May 2011, a 2.7 per cent increase from the previous year.Based on the current projection, the peak demand is expected to reach 21 Gig watts (GW) in 2020 and 25 GW by 2030.

Malaysia already has one of the highest rates of power consumption per capita among the emerging economies in the Asean region and as the country becomes more developed, the per capita power consumption is expected to increase even further.

The current problem is that 93.81 percent of the energy industry in the country relies on finite resources such as fossil fuels to generate power for electricity. Fossil fuels will be diminished very soon if it is not conserved and used with care. Other than that, excessive production of electricity will contribute to global warming and increase the carbon dioxide emission to the atmosphere.

This project is done to help decrease the electricity and energy wastage within the small scale commercial buildings such as offices, showrooms, and workplaces etc. with a lower cost and easier to build system.

1.3 Objectives

There are several objectives that this project needs to achieve within the timeframe given by the university:

- To identify the appropriate technique, hardware and software to develop the prototype.
- To develop the lab-sized prototype of the office to implement the system.
- To develop the system to help conserve energy.
- To conduct testing of the prototype through simulations and real time situations.

1.4 Scope of Study

My scope of study will be small scale offices and workplaces that have access to internet, intranet, able to accommodate sensors into their environment. My scope of study will be the offices in town and also the developing areas of the country.

My reason of choosing this scope is because nowadays, the trend that I observed is young generations and fresh graduates love to start up new businesses rather than working with existing company. With the rapid growth of entrepreneurship spirit within the nation, it is crucial to grow our business ways to help enhance the environment, rather than destroying them.

Business patterns have also grown from wanting product to demanding services. Consumers prefer companies with good customer service and hospitality rather than just looking at the product of the company. With automation systems like Smart Office System, this will enhance the productivity and hospitality of the company, hence increasing business value and customer services in the industry.

CHAPTER 2

LITERATURE REVIEW

This chapter covers the literature review of this project. In this chapter, we discussed the importance of energy-saving. Other than that, we also did several comparative studies, which are on the existing available systems in the market, hardware to be used, and the sensors that will be used in the prototype.

2.1 The Importance of Having an Smart Office Building

According to Sinopoli (2010), smart buildings are buildings that think for themselves. In his book, he mentioned that smart buildings are marriage of two technologies, which is old fashioned building management and technology. Technology and the systems in the buildings are enablers. Sinopoli (2010) also stated that the technology allows us to run the office more efficiently, to provide an energy-efficient and sustainable environment, to improve the building.

According to Binggeli (2003), in the year 2000, the earth population reached 6 billion people. With only 7% of the world population, America takes 30% of the world's energy, and building systems uses 35% from that to operate. He also stated in his book, that the world heavily reliant on electricity. Electric lighting produces heat, making consumer using air conditioner to cool down, which takes up more electricity. This leads to the greenhouse effect and ozone depletion and need to be stopped.

One way to reduce energy usage while improving building's condition according to Binggeli (2003) is to introduce controllers for the users. It can be low tech as shutters and shades for the office windows to get natural light from outside during daylight, up to using high tech gadgets such as automation systems to control energy usage in a building.

2.2 Comparative Study on Sensors

Microwave sensor and Passive Infrared (PIR) sensor

2.1.1 Overview

A motion sensor or motion detector is an electronic device used to detect the presence in the room, house or offices. Motion sensor is normally used in smart building system for security purposes or lighting system.

Motion sensor is connected to the heart of the system, which is the controller. When sensor detects motion it will send signal to the controller. Depends on the sensor purpose of security or lighting, controller will calculate and send the appropriate signal to the output which is either alarm or lighting.

There are two types of motion sensors, active sensors and passive sensors. Each of them uses different technology in detecting motion. Active sensor functions by emitting either one of these three energy, infrared light, microwave radiation and sound waves. On the other hand, passive sensors works by detecting the energy emit by the surrounding objects. This is different from the active sensor where the device itself emit the energy, in passive sensors the device is use to detects the energy.

Figure 1: Passive Infrared (PIR) sensor working principle

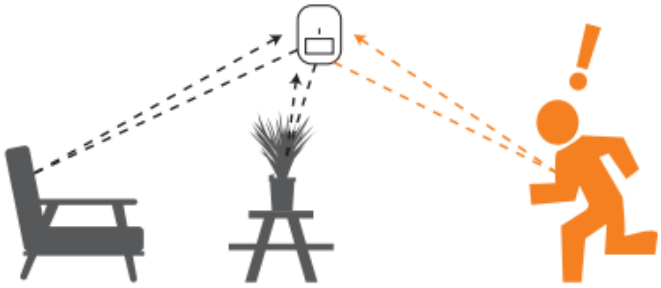


Figure 2: Microwave sensor working principle

2.1.2 Sensor Technology

Microwave sensor and Passive Infrared (PIR) sensor are most widely use sensors to detect motion. However, these sensors have different working principle on how they detect motion.

Passive infrared (PIR)

According to Wikipedia (2015), “Passive infrared sensors are sensitive to a person's skin temperature through emitted black body radiation at mid-infrared wavelengths, in contrast to background objects at room temperature. No energy is emitted from the sensor, thus the name "passive infrared" (PIR). This distinguishes it from the electric eye for instance (not usually considered a "motion detector"), in which the crossing of a person or vehicle interrupts a visible or infrared beam.”

Microwave

According to Wikipedia (2015), “These detect motion through the principle of Doppler radar, and are similar to a radar speed gun. A continuous wave of microwave radiation is emitted, and phase shifts in the reflected microwaves due to motion of an object toward (or away from) the receiver result in a heterodyne signal at low audio frequencies.”

According to another article in Wikipedia (2014), PIR detects motion through the changing of temperature between the object temperature in the sensing range and body temperature of human. This is one type of sensor under the group of passive sensor. Thus, PIR carries principle of passive sensor. To detect motion, PIR operates by detecting the infrared radiation emit or radiate by objects and living things. PIR devices do not emit or radiate any energy to detect motion.

While microwave, as stated by Safewise (2013), detects motion by studying the changes to the wave when a person walk into the radiation area. This principle is known as Doppler Effect. The devices will emit a microwave pulses and measure the reflection off a moving object.

2.1.3 Features

Comparison between sensors

Function/property	Microwave sensor	PIR sensor
Hidden in luminaire	●	●
Detects infra-red heat in motion	●	●
Detects objects in motion	●	●
Can be placed in a suspended luminaire	●	●
Detects through walls/glass	●	●
Adjustable detection range	●	● [1)]
Relay output	●	●
Adjustable off time	●	●
Adjustable lux threshold	● [2)]	●
on/off function	●	●
Absence dimming function	●	●
Slave connection	●	●

Figure 3: Comparison between sensors

Figure 3 shows the comparison between Microwave sensor and Passive Infrared sensor (PIR). There are six different features each of them has and another six similar features they both have in common.

Firstly, we will talk about the similarities between these two sensors. Both microwave sensor and PIR sensor have relay output. Relay output is the construction of the circuit in the sensor. Relay output means that, when sensor detects movement, the relay output will toggle and the switching in the circuit will switch ON. As a result, the relay at the output of the switch is activated and thus, lighting will get it supply through relay contact.

Microwave sensor and PIR sensor both have similar features that they have on and off function and they can adjust the off time. For example the PIR sensor, the electronic circuit has a mini electronic timer (T1). If the PIR relay is switched off, output relay will still be in on state for a duration decided by the timing capacitor.

These two sensors are also can be adjust their lux threshold. Lux is a unit of measurement for light and illumination. It is use in the sensor to measure the light intensity. User can set the lux threshold or the light intensity to turn on the operation timer. However, both of the sensors do not offer dimming function in their system. User need to be selective in their choice of lighting.

Steinel (2011) stated that both microwave and PIR sensors offers slave connection to the wiring of the sensor. Slave connection means that the sensor can have one or more other sensor with the same working principle a/s its slave. Slave can detect movement; however the range, lux, time and other variables cannot be adjusted. Slave has no intelligent on its own to dominate and controls the circuit independently. Nevertheless, slave will be a big help to its master when it detects motion and report to the master. Master then will decide on what decision it will send out.

Now, we come to the differences between these two sensors. There are feature that Microwave sensor offers but PIR sensor does not offer and vice versa. First feature is related to the feature with luminaire. Microwave sensor can be hidden in luminaire while PIR sensor can be placed in a suspended luminaire. Luminaire or it is also called light fixture or light fitting is an electrical device used to create artificial light by use of an electric lamp. When sensors are hidden in the luminaire or placed inside the luminaire, it will not be visible to the guest or intruder to the building.

Next is a difference between the operating principles of the sensors. PIR sensor can detect infrared heat in motion while microwave sensor can detect object in motion. PIR sensor detects the infrared that is emitting by the surrounding things including human in a certain area. It will calculate the temperature difference between the ambient temperature radiate by the surrounding things and infrared temperature radiate by the human with body temperature when coming to the sensing area. Microwave sensor works with the Doppler Effect principle. Doppler Effect is a change of frequency by a moving source of waves. This is why Microwave sensor can detect object is motion regardless it is alive or not.

Next feature is the feature offered by microwave sensor but not PIR sensor. Microwave sensor can detect through walls and glass. This feature is advantage and also disadvantage of it. Because Microwave sensor covers wide range of sensing area and can detect through walls, this will save money on buying more sensor to cover the area. However this sensor is not suitable for lighting system in a room. PIR sensor is more suitable for lighting system in a room since the sensor does not detect through walls and have low sensing area compare than microwave sensor, it will covers the room.

Last feature is on adjustable detection range. Microwave sensor has this feature but PIR sensor does not. However, the new invented PIR sensor already has

this feature. This feature is important as the wide sensing range may be a nuisance to user. For example if user forgot to close the door of a room, the lighting system in the room will keep on and off whenever user walks by the hallway in front of the room. This can be fix by adjusting the sensing range to the area where user want it to detect only.

For Smart Office System (SOS), PIR sensor is used to sense the motion for lighting system. One of the main reasons to choose PIR over microwave sensor is because SOS uses Raspberry Pi as the controller. RPi has a dedicated built in PIR sensor port. This saves user from buying an external converter to convert the signal between the input and output of the controller. PIR is also much reasonable and affordable in price compare to microwave sensor. Since SOS is more to lighting system in every room offices, user may need to buy more PIR sensor to cover the rooms lighting system. Furthermore, PIR does not sense through walls and thus, makes it the most suitable sensor to be used in the Smart Office System (SOS).

2.3 Comparative Study on the Existing System

Smart Office System, Vyrox Home Automation System, Fibaro System

3.1 The system

	SOS	Vyrox	`Fibaro
Compatibility	Can be accessed anytime from any place via any web enabled gadgets for control	Can be accessed anytime from any place via any web enabled gadgets for control	Compatible with majority of mobile phones and wireless products
The Intelligent System	Checks and monitors status of individual sensors connected to system, and if necessary, informs user of an incident.	Integrate and centralize all existing electrical and electronic systems, advanced access control system, advanced security alarm system.	Checks and monitors status of individual devices and, if necessary, informs you of an incident
Graphic interface	User-friendly and simple interface for user, and also administrator.	Straight forward interface with drag and drops the button right on the object and touch to control directly.	Simple configuration interface to change dependencies between devices, scenes and the entire system intelligence from any computer
Security	Able to measure time of person in toilet and compute to ensure safety of worker	Able to integrate and get input from paradox alarm system to activate automation sequences	Can be integrated with an existing alarm system
Powered by	Raspberry Pi	Intel processor, IBM server, ARM microprocessor, OMRON contactors	Fibaro System devices or any Z-Wave controller, Microprocessor control

Table 1: Comparison of the systems

There are three existing system for smart building system in our study, first is Vyrox Home Automation System, Second is Fibaro System and the third and last is the system that we plan to develop, Smart Office System. There are two type of study in this chapter, first is on the system and second is the feature of each system. The study on the system is divided into five type of system that each of them offers.

The first one is about the compatibility. Vyrox and SOS both can be accessed anytime from any place via any web enabled gadgets for controlling the building while Fibaro, is compatible with majority of mobile phones and wireless products. All three systems offer an easy access to monitor and control the system.

This brings us to the second type of system they offer, the intelligent system. Vyrox can integrate and centralize all existing electrical and electronic systems, advanced access control system, advanced security alarm system, HD CCTV surveillance system and also able to learn all of your remote controllers and integrate all into the system. On the other hand, SOS and Fibaro have quite similar intelligent system which is they can checks and monitors status of individual sensors connected to system, and if necessary, notify user of an incident.

The third type of study on the system is on their graphic interface. Fibaro system offers a simple configuration interface to change dependencies between devices, scenes and the entire system intelligence from any computer. Vyrox is a straight forward interface with drag and drops the button right on the object and touch to control directly. Lastly, our system SOS offers a user-friendly and simple interface for user, and also administrator.

The next type of study about the system involves the security system they offer. As mentioned before in the type of system they offer, Vyrox has advanced security alarm system with HD CCTV surveillance system. Besides that, Vyrox is also able to integrate and get input from paradox alarm system to activate automation

sequences. Fibaro can be integrated with an existing alarm system. Each system component may operate independently of the central unit. If the central unit is damaged and the system detects for example, a fire, each component will decide independently whether to pull up roller blinds, open the windows, doors, activate smoke venting system. Our system, Smart Office System is for small scale offices. SOS offers a security to the worker in the offices in terms of their health. SOS is able to measure time of person in toilet and decide whether the worker may not feeling well or has faint by the time and the movement of the worker in the toilet.

The fifth and the last study on the system involve the system itself. Vyrox is a smart home automation that uses Intel as its processor, IBM server, ARM microprocessor, OMRON contactors in its system. While Fibaro, is designed to be powered by Fibaro System devices or any Z-Wave controller, intel processor, SLC hard drive, MLC recovery disc and Microprocessor control. On the other hand, SOS is much simpler system that uses Raspberry Pi which is a low cost, credit card sized computer to sense, monitor and control the system.

Through all the five study on the existing system, we can conclude that SOS is the most suitable for our project. SOS target market is for small revenue offices that intend to cut cost and save energy in their office building. Vyrox and Fibaro is a complicated and suitable for home automation while SOS is dedicated for office's building with a simple system. That is why SOS is a perfect choice for our system.

3.2 Features

Features	SOS	Vyrox	Fibaro
Multi sensor	√	√	√
Dimension (LxWxH)	85.6 x 53.98 x 17mm	150 X 115 X 20mm	225 x 185 x 44mm
Intelligent object recognition			√
Multicontrol	√	√	√
Watch, monitor and control remotely	√	√	√
Notify user	√	√	√
Comfort		√	√
Analyse habits			√
Mobility	Ethernet, LAN	Wireless	Wireless
Installation	Easy	Complicated	Easy
Infrared control	√	√	
System backup and restore		√	
Location	Office	Home	Home
Alarm		√	√
Price per unit (RM)	500 - 600	9 000 – 22 000	5 000 – 20 000

Table 2: Comparison on the features

The second study on the comparative study on the existing system is the features each system offer. All systems offer a basic automation system which is sense, monitor and control. The more complex the system, the more features it offers. There are fifteen types of features to be compare between these systems.

All three systems is using multi sensor to sense parameter in the building it is installed. SOS is a simple system which uses two types of sensor, motion sensor and timer. Vyrox and Fibaro are a complex system that uses various type of sensor. Vyrox has motion sensor, vibration sensor, magnetic sensor, photoelectric beam

sensor and smoke detector sensor. Fibaro is using simple type of sensor that detects movement, temperature, light intensity and vibrations.

In terms of size, because all these systems involve building, we decided to study on the dimension of the controller. SOS with the Raspberry Pi B+ is the smallest with a credit card size computer with a dimension of 85.6mm x 53.98mm x 17mm. While Vyrox, is larger with a rectangular box shaped dimension of 150mm x 115mm x 20mm. Fibaro has the largest controller with also a rectangular box shaped with a dimension of 225mm x 185mm x 44mm.

On the intelligent object recognition and analyse user habit, only Fibaro system that offers this feature. One of the main features of the FIBARO Motion Sensor is its excellent ability to detect even the slightest motion; nothing escapes its attention. However, there is also a feature that both SOS and Vyrox offer but not Fibaro. The feature is infrared control. SOS uses Passive Infrared sensor to detect movement and send signal to Raspberry Pi to integrate with the lighting system. Vyrox system is able to learn all of your remote controllers and integrate all into the system. However, out of all these three systems, only Vyrox offers to backup and restore the system.

All three systems is a multicontrol that can be control using any devices that can be connected to the controller by wireless connection or HDMI port. These systems also offers mobility feature to the user.User can watch, monitor and control the system remotely by connecting to the internet. SOS, Vyrox and Fibaro system also will notify user of any incident happen in the building.

In terms of comfortability, because this feature requires high installation and maintenance budget, SOS does not offer this. Vyrox and Fibaro ensures the comfortability of the user by computing for example, the user behaviour and ambient temperature of the house and controlling the ventilation, air condition and curtain to gives comfort to the user and guests in the house.

SOS is a simple system designed for small revenue offices with the aim to save energy. With an easy installation and setup, user can use the manual provided to install and setup the sensors and controller. Fibaro system also has an easy installation. User can install and remove it easily. However this system is specially design for home automation only. A part from that, although Vyrox is also design for home automation system, this system requires a complicated installation that can only be done by the expert hired by Vyrox's company itself.

For feature like alarm, both Vyrox and Fibaro can be integrated with the home alarm system. Vyrox is able to integrate and get input from paradox alarm system and improve the security to the house. While Fibaro can be integrated with an existing alarm system for the security of the house. SOS does not offer this feature because it is located in the offices where this is not necessary. However, for the improvement of this system, it can be take into consideration.

The last one is the comparison between the prices of each system. Vyrox home automation system is quite pricey with the offer price range from RM9 000 to RM22 000. Fibaro System also offers price with quite similar to Vyrox. Fibaro is range in between RM5 000 to RM20 000. SOS on the other hand, offers much reasonable and affordable price ranging from RM500 to RM600.

From these studies, it is clearly shown that in order to provide services for a small scale office, Smart Office System (SOS) is the best choice for them. It is small in size, easy to install, simple and most of all, it is way cheaper and cost-saving.

2.4 Comparative Study on the Technology

Raspberry Pi, Arduino

3.1 Overview

Originally, both Arduino and Raspberry Pi were designed to be teaching tools, easy to learn to use, which is why they've become so popular. Raspberry Pi originated from the UK by the inventor Eben Upton and his friends at the University of Cambridge's Computer Laboratory. Raspberry Pi was designed to be aninexpensive, easy to hack computer to increase programming skills. On the other hand, Arduino was born in Italy. It was named after the bar where its inventor Massimo Banzi and his colleagues first came up with the idea. Banzi, a teacher at the Interaction Design Institute Ivrea, wanted a simple hardware prototyping tool for his design students.

As teaching tools, both Arduino and Raspberry Pi are suitable for new users. But after deep researching and examining their hardware and software that it becomes clear they're used for very different types of projects.

3.2 Hardware

	Arduino Uno	Raspberry Pi Model B
Price	$30	$35
Size	7.6 x 1.9 x 6.4 cm	8.6cm x 5.4cm x 1.7cm
Memory	0.002MB	512MB
Clock Speed	16 MHz	700 MHz
On Board Network	None	10/100 wired Ethernet RJ45
Multitasking	No	Yes
Input voltage	7 to 12 V	5 V
Flash	32KB	SD Card (2 to 16G)
USB	One, input only	Two, peripherals OK
Operating System	None	Linux distributions
Integrated Development Environment	Arduino	Scratch, IDLE, anything with Linux support

Table 3: Specification for Arduino Uno vs. Raspberry Pi Model B (Orshini, 2014)

The Raspberry Pi is 40 times quicker than an Arduino in the matter of clock pace. Significantly for Arduino, Pi has 128,000 times more RAM. The Raspberry Pi is a free PC that can run a real working framework in Linux. It can multitask, support two USB ports, and unite remotely to the Internet.

It may sound like Raspberry Pi is better than Arduino, however that is just concerning programming applications. Arduino's straightforwardness makes it a better choice for solely hardware ventures.

As indicated by Fried (2014), the organizer of Adafruit, a DIY gadgets store that offers parts and packs for both Arduino and Pi ventures, about her feeling on their disparities. A MIT taught engineer whose mission in life is to teach gadgets to individuals of all ability levels, Fried knows both platforms better than most.

"Arduino does have a 'real-time' and 'analog' capability that the Pi does not: This flexibility allows it to work with just about any kind of sensor or chips," Fried (2014). "The Pi is not as flexible; for example, reading analog sensors requires extra hardware assistance. There are also thousands of tutorials on hooking an Arduino into just about every kind of part. On the other hand, the Pi benefits from decades of Linux software, so they're both great choices."

The Arduino IDE is fundamentally less demanding to use than Linux. Case in point, on the off chance that you needed to compose a system to blink a LED with Raspberry Pi, you'd have to introduce a working framework and some code libraries. On Arduino, you can get a LED light to flicker in only eight lines of code. Since Arduino isn't intended to run an OS or a great deal of programming, you can simply connect it and begin. Raspberry Pi can multitask processes—it can run multiple programs in the background while activated.

On the other hand, you can leave an Arduino switched on as it conducts a single process for a long time, and just disconnect it when you're not using it. This is why Fried would recommend the Arduino for beginners before she would the Pi:

> “The Arduino is simpler, harder to 'break' or 'damage' and has much more learning resources at this time for beginners,” Fried (2014). “With the Pi you have to learn some Linux as well as programming—such as Python. The Arduino works with any computer and can run off of a battery. You can also turn it on and off safely at any time. The Pi setup can be damaged by unplugging it without a proper shutdown.”

For Smart Office System, it is more suitable to use Raspberry Pi for its ability to conduct and control more processes at one point, Pi’s much bigger RAM and its ability to contain OS, as the SOS system need the processor to control and monitor multiple motion sensors at one time, also to have an user interface for the user to view the updates on the sensors for security and environmental purposes.

2.5 Gaps in the Literature and Way Forward

Currently there are two smart systems used for buildings, Vyrox home automation system and Fibaro system. These two systems offer various kinds of control, monitor and sense. They also has other additional option like alarm, CCTV surveillance, weather forecast, and can ensure the comfortability of user and guests in the house by controlling the parameter such as ventilation and air conditioner.

Furthermore, these two systems are using high tech systems in its construction. For example, Fibaro system uses a new Z-wave wireless technology which the switch operates on a dedicated radio frequency ensuring that it does not interfere with Wi-Fi or other wireless communications in the house. While Vyrox on the other hand, link to the internet through the cloud on all major operating systems. Thus, user can control all aspects in their home with only a simple touch of a finger.

There is an old saying, with every bad thing there is a good side, but with every good thing there is a bad side. Same goes with these two systems. No matter how great these systems are, they are exclusively designed for smart house system and are not suitable for offices. These systems are costly and it is too complicated for small scale office with small revenue margin to invest in such expensive system just to get a simple function, which is lighting control and a simple safety feature. In addition to that, an average people spent half of their day at work rather than being at home. This result in high energy usage recorded at offices building and other workplaces instead of houses. A smart system that is suitable of small revenue margin offices with reasonable price need to be designed to solve this problem.

Running on an easy to get, easy to learn processor, Raspberry Pi makes it a much more convenient, cost saving and easy choice compared to the other systems. By creating a simple, cheap and easy to use security and power saving system, Smart Office System helped fulfilling the needs of small scale offices in a much convenient and cost saving way.

CHAPTER 3

METHODOLOGY/PROJECT WORK

This chapter explains the way and the methods used to develop the project. This includes the project and system development methodology, data collection approaches to be used to collect information, Gantt chart, key milestones and list of tools to be used in the project.

3.1 Project Development Methodology

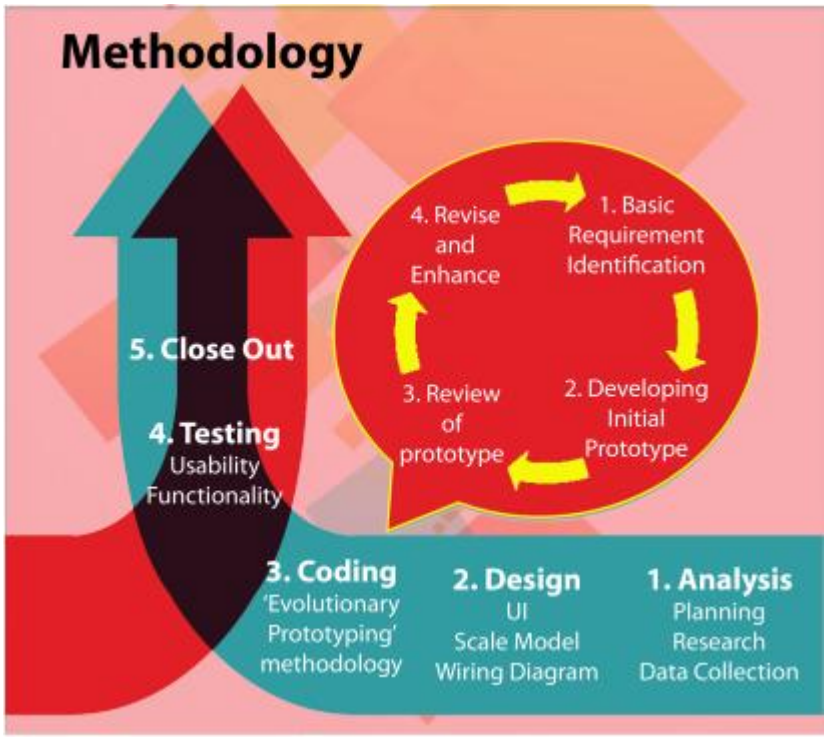


Figure 4: Project methodology + SDLC

3.1.1 Analysis

In the planning phase, research were done on the proposed title, and meet with assigned supervisor for discussion regarding the topic, to make sure that the topic is within the scope, feasible accordance to the time and cost constraint. After the title is finalized, we started the project with a base timeline on how the project will be carried out in the future. Next, the project background, problem statement, scope of study, and project objective were drafted. Then, the steps were continued with literature reviews and comparative studies.

Literature review is crucial for a research because it helps the student to understand the topic even more by reading and researching someone else's previous researches and works. First, research was made on the importance of energy saving, specifically in office buildings. From there, comparative studies were made on several elements in the project.

In order to get a more realistic and marketable results, the project was continued with data collection process. In this step, data were collected from real life people to get feedback and comments regarding the project.

Pre-development interviews were held to get feedbacks on what do small scale businesses want and need in the prototype. Next, post-interviews were done to make sure that the prototype is according to their needs and is suitable and plausible to be implemented in real life.

3.1.2 Design

Scale model is a building prototype model, used as the office prototype to implement my Smart Office System. In this phase, the scale model was designed using SketchUp software to come up with the design of the office. This is to estimate the material needed to build the prototype.

When the scale model design is done, the wiring design diagram was created to estimate the number of sensors needed, lengths of wire needed etc. An instrument and electrical personnel was consulted to achieve the right and suitable wiring diagram for the project.

Next, the interface was designed using FluidUI. FluidUI is used to design only the interface with no functionality. This is done to make sure the author have an idea of what to code during the actual interface development phase.

Then the Pi is connected to the internet for easy access. Then a system was designed using Tkinter for the system. Tkinter is the Python interface to the Tk GUI toolkit shipped with Python.

3.1.3 Coding

For the system development, Evolutionary Prototyping Model was used. According to Tutorialspoint.com, the Software Prototyping refers to building prototypes which display the functionality of the product under development but may not actually hold the exact logic of the original software.

Software prototyping enables us to understand customer requirements at an early stage of development. It helps get valuable feedback from the customer and helps software designers and developers understand about what exactly is expected from the product under development.

Below are the basic steps in evolutionary prototyping model:

a. Basic Requirement Identification

   Understanding the very basics product requirements especially in terms of user interface and system requirements.

b. Developing the initial Prototype

   The initial prototype is developed in this stage, where the model is showcased and user interface is provided (FYP 1 deliverables). These features may not exactly work in the same manner internally in the actual software developed and is used to give the same look and feel to the evaluator in the prototype developed.

c. Review of the Prototype

   The prototype developed is then presented to the supervisor of the project. The feedback is then collected and used for further enhancements in the prototype under development.

d. Revise and enhance the Prototype

   The feedback and the review comments are discussed during this stage and the changes accepted are again incorporated in the new prototype developed and the cycle repeats until expectations are met.

3.1.4 Testing

During testing phase, there are several tests that were carried out throughout the project development process. First, the sensors are installed and tested for the functionality. Next, the interface development phase did testing and amended any errors before finalizing the design. Finally, the functionality testing is done with focus group, which consists of the small business owners and employees by running the prototype in front of them and has them to evaluate the functionality of the system using surveys and interviews.

3.1.5 Close-out

Project is finished and reports are done in the close-out phase.

3.2 Data Collection Approach

For this project, several types of data collection were done to help enhance the model:

1. Observation

   To make sure my plans and designs of the model is realistic and plausible, I visited and observed several small scale offices in Kuala Lumpur as a reference to develop my prototype.

2. Interview

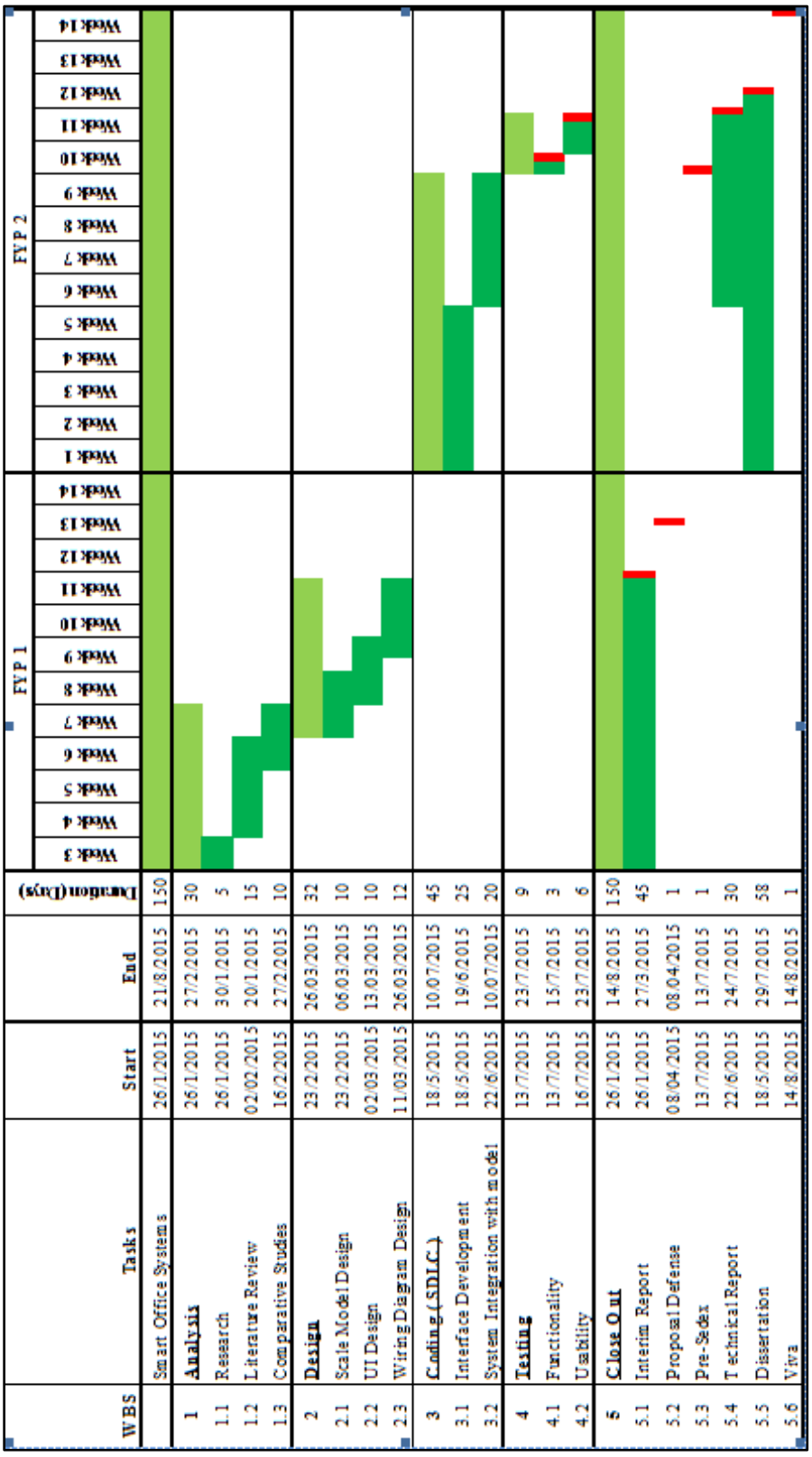
   For interview, one session was done. It was the pre-development interview. This is to harvest information on the utility costs of the firm/company, the struggle to keep up with the overhead charges with their small margin revenue, their awareness on energy saving and office automation systems and others.

3. Survey

   When the prototype is done, functionality testing was done with a group of 20 Electrical & Electronics students to verify the functions of the circuits and wiring works.

   After the prototype is fully developed and done, usability testing was done to the focus group, which is the selected crowd of respondents, to get their feedback and comment on the prototype developed. After the demonstration, the respondents were given a survey form regarding the prototype for them to fill in.

3.3 Gantt Chart & Key Milestone



3.4 Tools/Equipment to Be Used

3.4.1 Raspberry pi Model B+

Figure 5: Raspberry Pi Model B+

Specifications

Chip Broadcom	BCM2835 SoC
Core architecture	ARM11
CPU	700 MHz Low Power ARM1176JZFS Applications Processor
GPU	Dual Core VideoCore IV® Multimedia Co-Processor Provides Open GL ES 2.0, hardware-accelerated OpenVG, and 1080p30 H.264 high-profile decode Capable of 1Gpixel/s, 1.5Gtexel/s or 24GFLOPs with texture filtering and DMA infrastructure
Memory	512MB SDRAM
Operating System	Boots from Micro SD card, running a version of the Linux operating System
Dimensions	85 x 56 x 17mm
Power	Micro USB socket 5V, 2A

Connectors

Ethernet	10/100 BaseT Ethernet socket
Video Output	HDMI (rev 1.3 & 1.4) Composite RCA (PAL and NTSC)
Audio Output	3.5mm jack, HDMI
USB	4 x USB 2.0 Connector
GPIO Connector	40-pin 2.54 mm (100 mil) expansion header: 2x20 strip Providing 27 GPIO pins as well as +3.3 V, +5 V and GND supply lines
Camera Connector	15-pin MIPI Camera Serial Interface (CSI-2)
JTAG	Not populated
Display Connector	Display Serial Interface (DSI) 15 way flat flex cable connector with two data lanes and a clock lane
Memory Card Slot	SDIO

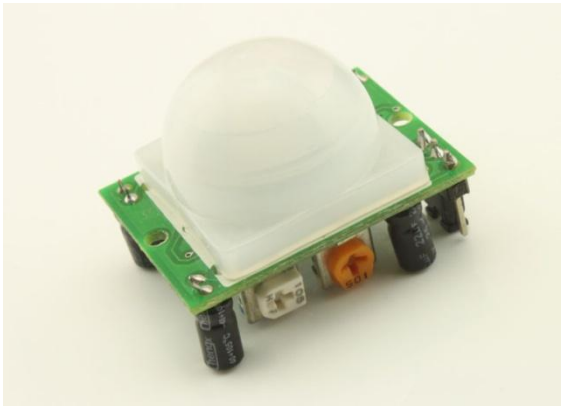
3.4.2 LCD Touch Screen Display

3.2" TFT LCD Module 240x320 RGB Touch Screen Display Monitor for Raspberry Pi

Feature

Type TFT	Support Raspbian system that allows your system to: Support for video playback (MP4 and other formats) Support for touch control camera (17 kinds of camera mode) Support soft keyboard (mouse and keyboard can also be controlled from the system)
SPI Interface	
Touch panel control chip XPT2046	
LED backlight	
Resolution of 320x240 (Pixel)	
Size ratio 4:3	
Support access raspberry pi, easier to use	

3.4.3 PIR Sensor



Length: 24.03mm/0.94in
Width: 32.34mm/1.27in
Screw hole distance: 28mm
Screw hole diameter: 2mm
Height (with lens): 24.66mm/0.97in
Weight: 5.87g/0.2oz
Output Digital pulse high (3V) when triggered (motion detected) Digital low when idle (no motion detected)
Sensitivity range Up to 20 feet (6 meters) 110° x 70° detection range
Power supply 3V-9V input voltage, but 5V is ideal.

CHAPTER 4

RESULTS AND DISCUSSION

This chapter covers the results and data collected of the project. This chapter includes the result from the interview with business owner, proposed sketch design of the office layout made in Sketchup and photos of completed prototype.

4.1 Interview results

To collect data to be used in the project, I interviewed the assistant manager Norelya Adrisha bte Che Adnan to a small company called Malplus Logistic Sdn. Bhd. in Klang. Below is the answer to the question asked during the interview:

1. How much do your company spend for electricity monthly?
   RM300 to RM350 monthly.

2. In what ways do this expenses affect your company?
   Since we are a small company, high utility bills affects us in terms of reducing our net profit. If these bills keep increasing, we won't be able to last long.

3. What are your solution to reduce the electricity usage?
   There a few solution that we have come up. We stick notes to desktop and switches in the office to remind the staff to shutdown their computer before leaving the office and also to switch off the lights and air conditioner of certain area when not in use. We also decided to restrict and not encouraging the staff to work overtime. However, this method has cost us in productivity to meet certain deadlines.

4. Do you think that it is necessary to save energy?
   Yes, definitely.

5. Would you consider to have a smart device installed in your office to help reduce electricity usage and reduce utility bills for a long term usage?
   Yes, I would consider it.

4.2 SketchUp design

Before designing and developing the prototype scale model, SketchUp software was used to design the whole building.

The office consist of several spaces, which is the reception area, meeting room, work areas, pantry, photocopy and storage room, lounge area, separate rooms for higher managements and also toilets.

4.3 Completed prototype

With the completed office design on SketchUp, the prototype scale model of the building was built from scratch.

Figure 7: Photo of completed prototype model

4.4 GUI design

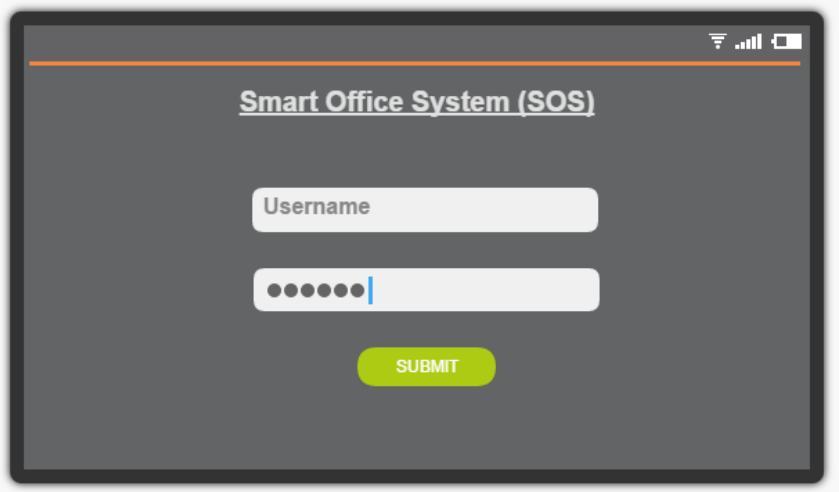


Figure 8: Log in interface to SOS

The system will prompt username and password to log into Smart Office System, to prevent any out of authority changes in settings and to limit the number of people accessing the system for better control.

When log in is successful, the home page will appear. With this feature, the user can detect whether all the rooms are clear to shut down or not every day and to prevent long lasting energy wastage by letting lights on all day.

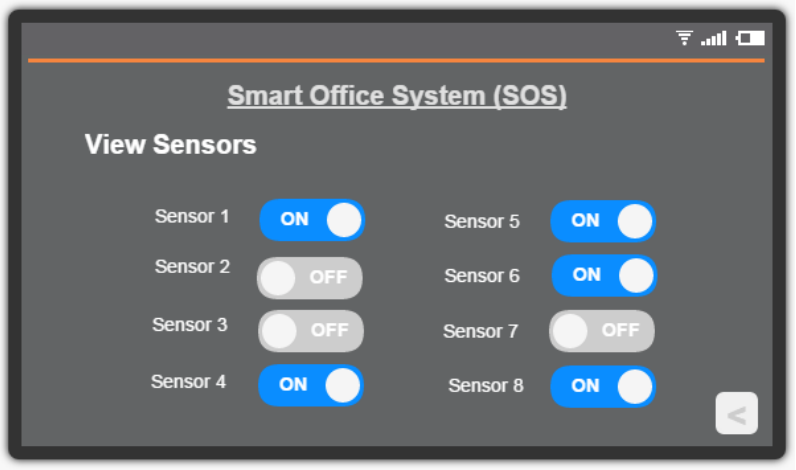


Figure 9: Home page

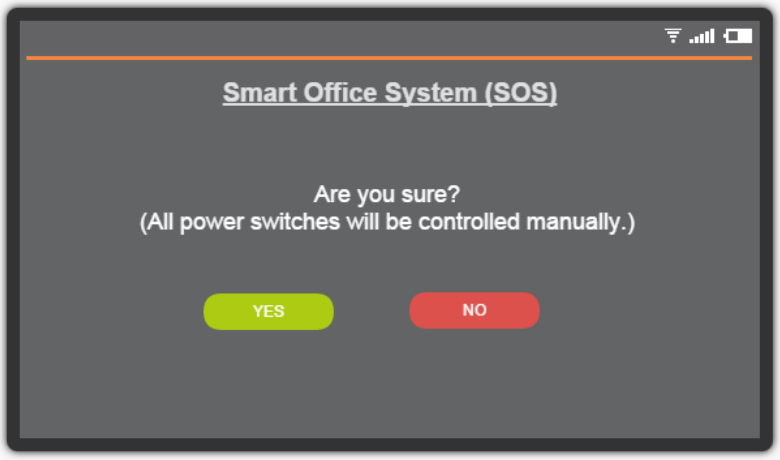


Figure 10: Switch Off confirmation page

When the user chooses the ‘Off’ button, a confirmation page will pop up to double confirm whether the user wants to turn the system off or not. System is turned off during reinstallations, upgrades of hardware, addition of hardware or maintenance. Other than that, it is not necessary to turn off the system.

4.5 Finalized GUI Design

The first interface of the program (Figure 11) displays the Turn On SOS button, that will turn on the automated system to control the lighting of the office. The sensor status will display the sensors and lights status in the building, whether it is turned on or off and whether the sensor triggered movements indicating there are people in the room or the room is empty.

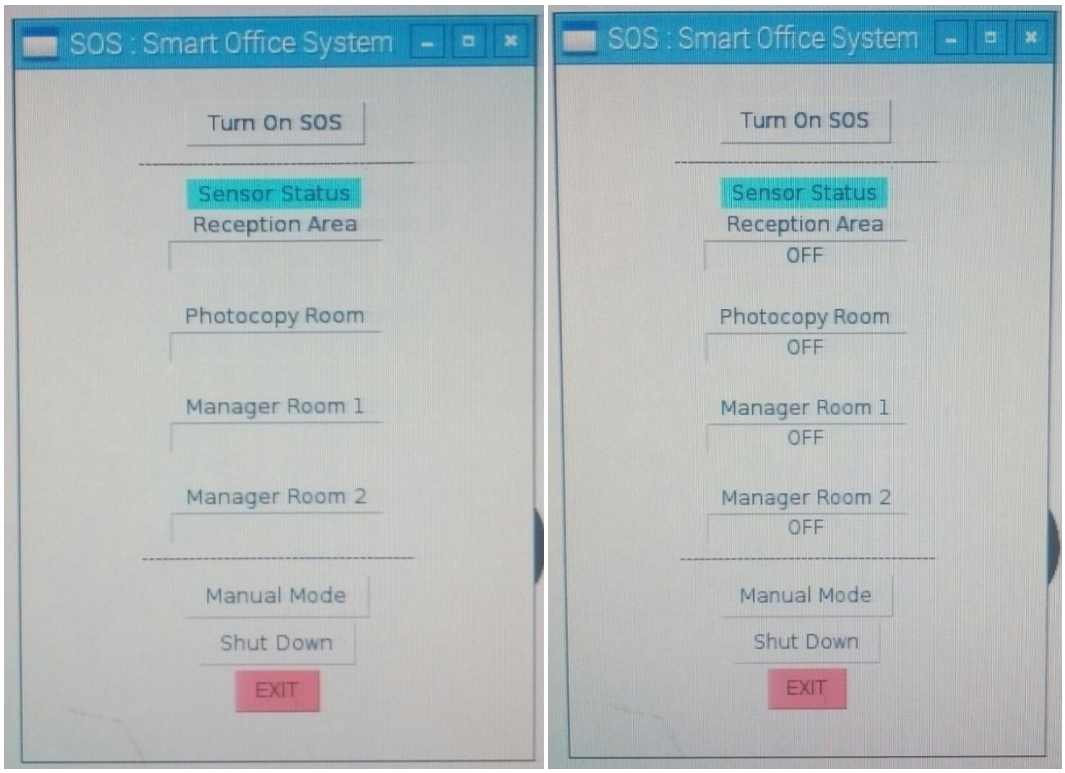


Figure 11: First interface of Smart Office System

When the user pressed the Manual Mode button, the interface will switch to manual interface (Figure 12). In this interface, user can control the lighting manually from one point.

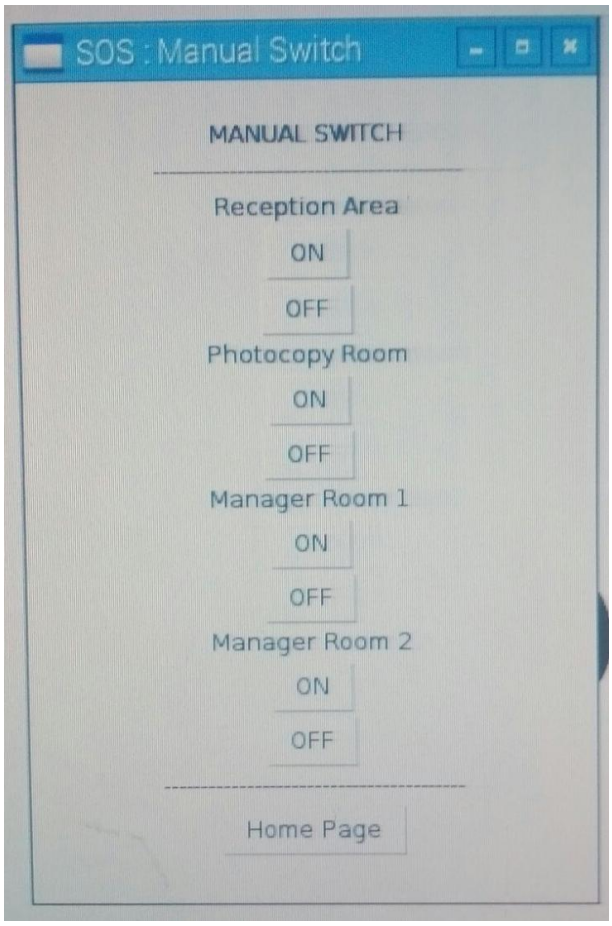


Figure 12: Manual mode interface of SOS

When the user wishes to shut down the building, the user will press Home Page button to go back to the interface in Figure 11 and press Shut Down. And then exit the system by pressing Exit button.

4.6 Source Code

Snippet of the codes from Smart Office System program:

```
import RPi.GPIO as GPIO
import time

GPIO.setmode (GPIO.BCM)

SENSOR1=21
SENSOR2=16
SENSOR3=12
SENSOR4=20

BULB1=5
BULB2=6
BULB3=19
BULB4=13

GPIO.setup ( SENSOR1, GPIO.IN )
GPIO.setup ( SENSOR2, GPIO.IN )
GPIO.setup ( SENSOR3, GPIO.IN )
GPIO.setup ( SENSOR4, GPIO.IN )

GPIO.setup ( BULB1, GPIO.OUT )
GPIO.setup ( BULB2, GPIO.OUT )
GPIO.setup ( BULB3, GPIO.OUT )
GPIO.setup ( BULB4, GPIO.OUT )


def motion1 ():
   global x
   while (1==1):
         if GPIO.input (SENSOR1) == TRUE:
            GPIO.output(BULB1) == TRUE
            Time.sleep (5)
        Else:
            GPIO.output(BULB1) == FALSE
            Time.sleep (5)
```

CHAPTER 5

TESTING RESULT

This chapter covers the results from the testing ran, which is functionality testing and usability testing.

5.1 Functionality testing

To identify the effectiveness and the functions of the circuits and wiring works on the prototype, a functionality testing session were done with a group of 20 selected Electrical & Electronics Department students to help verify the functionality of the system.

The following survey form was given to the respondents to fill in while testing and watching the demonstration of the prototype.

Please mark tick (√) wherever applicable during the commencement of the demonstration. Thank you for being a part of our testing team.

Components on circuit	Working	Not working
Sensor 1		
Sensor 2		
Sensor 3		
Sensor 4		
Light bulb 1		
Light bulb 2		
Light bulb 3		
Light bulb 4		
Comparator		
Breadboard		
Wiring		
Controller		
Overall system		

The following is the result of the testing ran with the group of EE students:

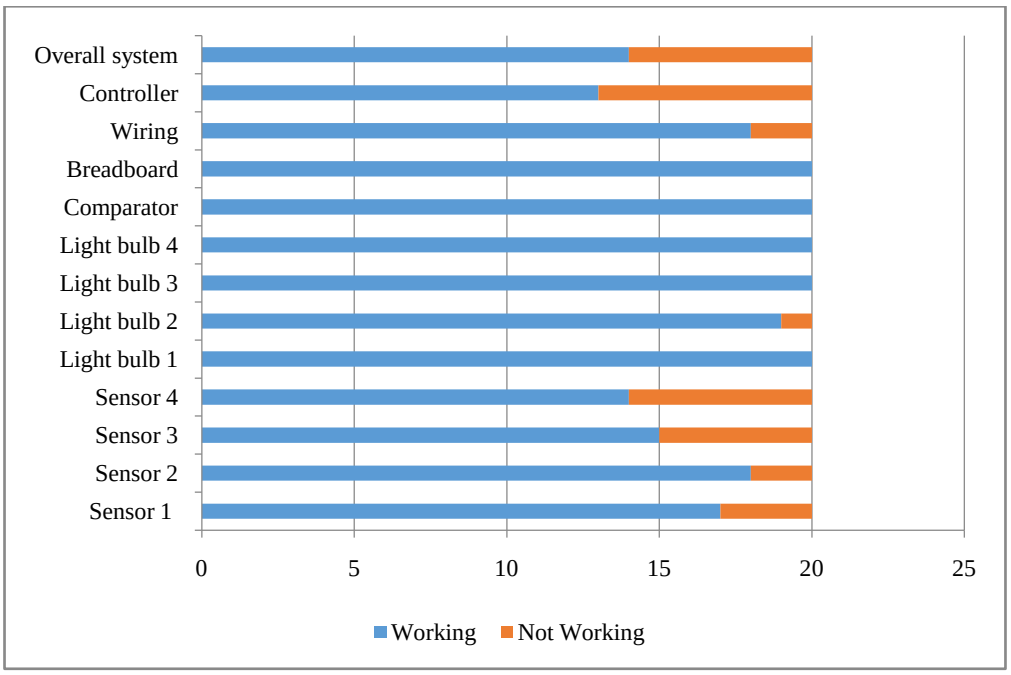


Figure 13: Summary of the functionality testing by respondents

The graph (Figure 13), shows the summary of the entire demonstration and testing with the selected respondents. Overall, the entire system works perfectly 70% of the time.

On average, the sensors failed to function about 4 times, which is 20% of the time. With further discussions with the respondent, the problems that occurred during demonstration that disrupted the sensors functionality were found out, which are the sensors were poorly placed (signals were blocked by certain components on prototype) and the disturbance from the external noises (sudden movement of prototype, heat detected from outside prototype etc.).

After the session with the respondents, changes were made on the prototype according to the result and discussion from the functionality test, to ensure that none of the same problem reoccurs during the usability testing demonstration and presentation session.

5.2 Usability Testing

Usability testing was done to get feedbacks and comments from respondents on the overall system, from user's point of view.

The usability testing was conducted with 50 selected respondents as the potential users of Smart Office System which consist of business owners and shopkeepers in the area of Sri Iskandar. The testing was done to evaluate the system in terms of its usability, accuracy and user-friendliness when using the entire system on the prototype.

The testing was performed as follows:

1. The survey forms were given out to the respondents prior to the testing.

2. Respondents were briefed about the objective of the session and what to do during the testing session. They were to test out the system without any help from developer.

3. Respondents tested the system as they answered the questions. All questions were made compulsory in order to ensure the quality of the feedback and results of the testing.

4. The results from the testing were analyzed and transformed into graphical facts using charts.

Stated below are the questions asked during the usability testing:

Thank you for taking part in this testing session.

Please answer the following questions after you have tested out the prototype. Should you have any questions/doubts, feel free to ask the developer on scene.

Q1. The interface is easy to understand.	☐ Yes	☐ No
Q2. The overall site is attractive.	☐ Yes	☐ No
Q3. It is easy to understand the functions of the system.	☐ Yes	☐ No
Q4. The system is relevant.	☐ Yes	☐ No
Q5. I would use the system, should I have a business building.	☐ Yes	☐ No
Q6. The system needs more functions/features.	☐ Yes	☐ No

Rate the system accordingly with the scale (1-poor, 5-excellent)

Q7. Rate the interface. ☐

Q8. Rate the system. ☐

Q9. Rate the overall demonstration. ☐

Q10. Rate the learning curve around the system. ☐

Any ideas on improvements/further development of the system?

_____

_____

The charts below picture the summary of the entire testing session:

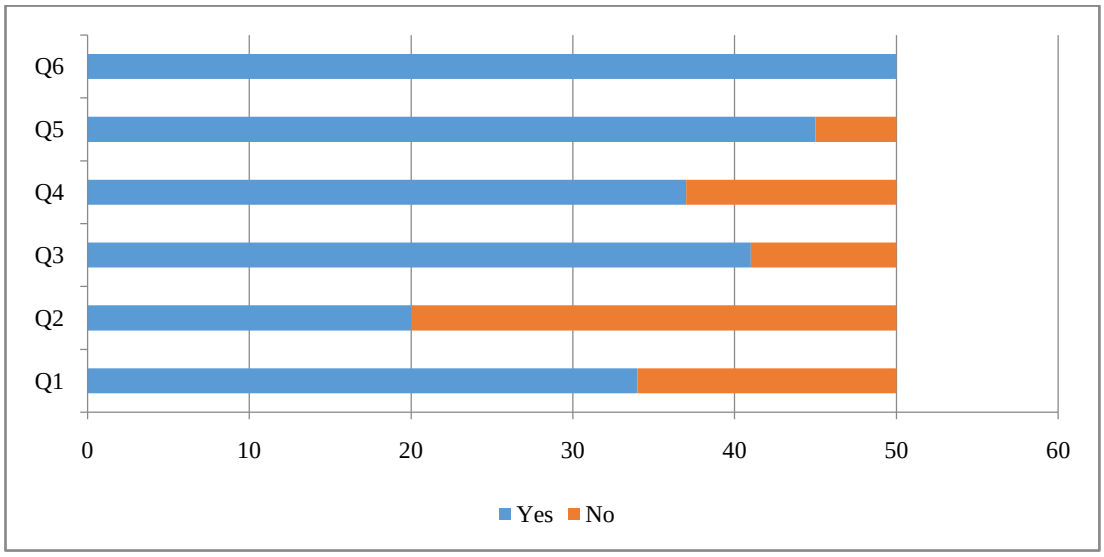


Figure 14: Summary of the answers for Q1 to Q6 of the survey

On the first part of the survey, 6 questions were asked, mainly focused on the system user-friendliness, the interface of the system and the learning curve of the system. Deducting from the graph (Figure 14), the respondents were most unsatisfied with the interface design. These are some of the comments given by respondents regarding the interface of the system:

> *"…the interface could be more interesting to attract users, if the product is to be commercialized."*
>
> *"…the colors are quite dull and not interesting."*
>
> *"…should enhance the home interface to give out more information regarding the system…"*

From the low level of satisfaction in the interface designs, it is directly related to low level of satisfaction in the first question, which is the ease of understanding in the interface of the system.

In question 6, 100% of the respondents thought that the system could add more features to enhance the system even further. These are some of the comments given regarding the additional features that should be added to the system:

"...should have security features or alarms to trigger over-usage of electricity."

"...can add in functions to control not just the lighting, but the overall power in the building, such as the computers/printers in the office."

The second part of the survey feedbacks are represented in the chart below:

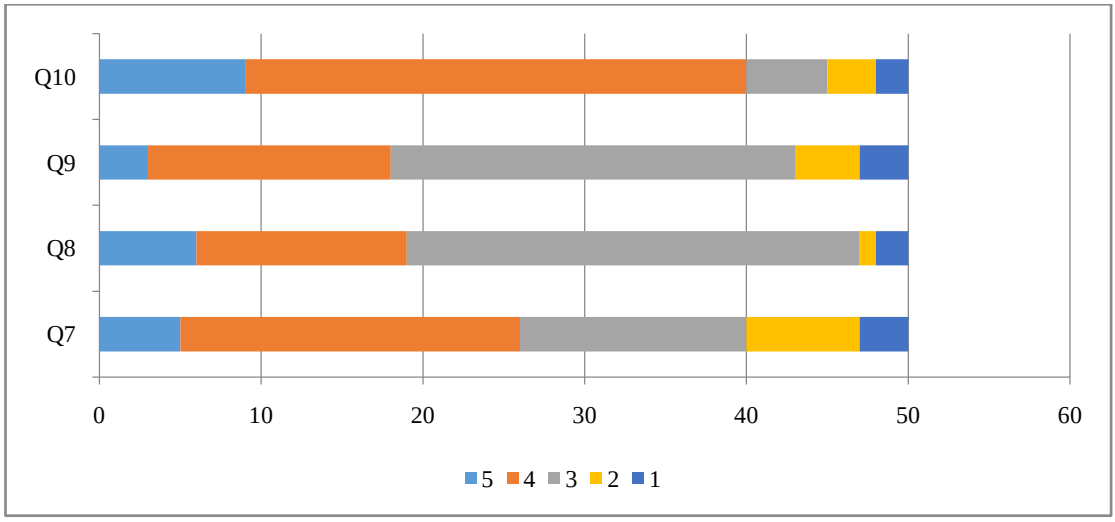


Figure 15: Summary of Q7 to Q10 from the survey

Further into the analysis of the testing result, most of our respondents are satisfied with the ease of learning the navigation around the system. (Figure 15, Q10) 40 respondents rated 4's and 5's for the soft learning curve of the system. This showed that the respondents were happy with the easiness of the system.

From the testing session, it is safe to conclude that the respondents are happy with the current system but they were expecting more functions and features to be added to the system in order to further enhance and improve the system as a whole. Other than that, they were also expecting a much presentable interface design to add commercial value to the final product.

CHAPTER 6

CONCLUSION AND RECOMMENDATION

This chapter will cover the conclusion of the whole project and also the improvements that can be made to further enhance the project's final product.

6.1 Conclusion

Throughout the entire the project, all key milestones were met without problems and all of the objectives were met.

The appropriate technique, hardware and software needed to develop the prototype were identified, which is the Raspberry Pi, PIR sensors and also the TKinter to develop the interface and the system. SketchUp software was also used to design the layout of the prototype office.

Other than that, the lab-sized prototype of the office to implement the system were also successfully developed using the design from SketchUp. After the prototype is done, the system integration and the system development were successfully done. Testing is also successfully ran by chosen group of respondents to verity and to learn about the effectiveness of the system.

Users, in summary were satisfied with the overall performance of the system and had suggested a few additional functions to be added to final product that is included in the Improvements section of this report.

6.2 Challenges faced during the project execution

During the execution of this project, there were a few challenges faced by the author. One of it was, during the integration phase where the sensors wiring system is to be merged and integrated with SOS python program, the author had trouble recalibrating and assigning the sensors to the respective GPIO pins on the Raspberry Pi.

Other than that, the author also had some difficulties adjusting the sensitivity of the sensors to control the sensors as the prototype used is very small. The sensor had become too sensitive and was detecting everything, making it less reliable in terms of the system objective.

Apart from the technical difficulties, there are also some other difficulties faced. As a student in Business Information Systems, the author had no prior experience in handling and installing wiring system. To be able to execute this project successfully, a student from Electrical and Electronic Department were asked to help out with the project, to make sure all wiring work is done perfectly and without problem.

Although the author faced a lot of difficulties during the project execution, the project is able to close out successfully, thanks to the help from colleagues, supervisor, lecturers, friends and family.

6.3 Improvements

The first phase of the project is well accepted by the respondents however, there are certain features and functions should be included in the system. For future improvements, I would suggest security features such as timer and alarm to trigger in case of emergency to be implanted in the system. For example, the sensor is installed in the toilet, should the user stayed in the toilet for too long, this could indicate that the user had fell or fainted and the system could be triggered to inform the security guards to check upon the earlier mentioned user that are in the toilet.

Other than that, I would also suggest to improve the scale of the prototype, by testing it on a real scale, which is to install the system into a real office building to test its reliability as this version is tested purely on a lab scale prototype.

REFERENCES

Websites

Alibaba.com (2015). *Vyrox Smart Home,Smart House & Home Automation System - Buy Smart Home Product on Alibaba.com*. Retrieved 24 February 2015, from http://www.alibaba.com/product-detail/Vyrox-Smart-Home-Smart-House-Home_122536444.html

Fibaro.com,. (2015). *FIBARO Motion Sensor - Home Automation and Wireless* Smart Home Solution.. Retrieved 24 February 2015, from http://www.fibaro.com/en/the-fibaro-system/motion-sensor#

Forum.lowyat.net,. (2015). *(WTS) ZWave Smart Home Integrated with Security Solution*. Retrieved 24 February 2015, from https://forum.lowyat.net/topic/3485359/all

Motion detector. (2015, January 26). In *Wikipedia, The Free Encyclopedia*. Retrieved 10:31, February 23, 2015, from http://en.wikipedia.org/w/index.php?title=Motion_detector&oldid=644293969

Passive infrared sensor. (2014, December 20). In *Wikipedia, The Free Encyclopedia*. Retrieved 10:46, February 23, 2015, from http://en.wikipedia.org/w/index.php?title=Passive_infrared_sensor&oldid=638877753

Readwrite.com,. (2015). *Arduino vs Raspberry Pi*. Retrieved 28 February 2015, from http://readwrite.com/2014/05/07/arduino-vs-raspberry-pi-projects-diy-platform

Tutorialspoint.com,. (2015). *Python GUI Programming (Tkinter)*. Retrieved 1 March 2015, from http://www.tutorialspoint.com/python/python_gui_programming.htm

Vyrox,. (2015). *Home - Malaysia Smart Home System Expert | Vyrox.com*. Retrieved 25 March 2015, from http://vyrox.com/

Books

Albert Ting-pat So, W. L. (1999). *Intelligent Building Systems.* Kluwer Academic Publishers.

Binggeli, C. (2003). *Building Systems for Interior Designers.* John Wiley & Sons,Inc.

Clements-Croome, D. (2004). *Intelligent Buildings : Design, Management and Operation.* Thomas Telford.

Sinopoli, J. (2010). *Smart Building Systems for Architects, Owners, and Builders.* Elsevier.

APPENDICES

- Photos of scale model

Figure 16: Front door view of scale model

Figure 17: Reception area

Figure 18: Meeting room

Figure 19: Workplace & lounge area