



Internship Report

Design and Development of Smart Low-Cost Home Systems using Raspberry Pi

Submitted to

Department of Mathematics and Natural Sciences

BRAC University

By

Nafis Rafat (ID. 13115001)

Department of Mathematics and Natural Sciences

BRAC University

December, 2017

DECLARATION

I do hereby declare that the internship report titled “Design and Development of Smart Low-Cost Home Systems using Raspberry Pi” is submitted to the Department of Mathematics and Natural Sciences of BRAC University in partial fulfillment of the Bachelor of Science in Applied Physics and Electronics. This was not submitted elsewhere for the award of any degree, publication or other similar purposes.

Date:

Submitted by

Nafis Rafat

Student

ID. 13115001

Supervised by

Professor Dr. Adnan Kiber, PhD

Department of Electrical and Electronic Engineering

University of Dhaka

ACKNOWLEDGEMENT

At first, I would like to thank Almighty Allah for giving me perseverance and mental ability for the successful completion of this project and paper. I would also like to express my gratitude and thank Prof. Dr. Adnan Kiber, my supervisor for my internship, who has helped me develop the idea and design, and improve on all aspects of the task at hand. He is certainly an inspiring character to work with and get encouragement from. I look forward to working with him in the future.

ABSTRACT

This research work aims to design and develop a smart low-cost home automation system with existing technology. The home automation becomes important, because it gives the user the comfortable and easily for using the home devices. The implementation and design of wireless home automation control used two methods, WLAN technology and RF remote control handheld to control of the selective home devices with integral security and protected system. The system is low cost and flexible with the increasing variety of devices to be controlled. Smart home automation has attracted the interest of the research community during the last decade. In today's world automation plays a very important role and in this project an automated way of controlling home appliances through human interaction as well as through self-control of the system itself is provided. The manual mode helps user to control home appliances automatically using PC or any Wi-Fi enabled Mobile phone in the same local area network. The system designed and implemented here uses simple easy-to-use programmable devices like the Raspberry Pi and other hardware that can be easily sought out and implemented including relays and motor controllers. One of the main aims of this paper is to establish that home automation can be cheap to set up, if one does not want to purchase existing expensive gadgets that are available on the market. It was possible to successfully meet most of the objectives required. However, there is room for improvement in terms of both hardware and software in order to expand the functionality of the whole system for a range of other uses and features.

TABLE OF CONTENTS

CHAPTER 1	PAGE
1.1 INTRODUCTION	6
1.2 LITERATURE REVIEW	8
1.3 OBJECTIVE	13
1.4 PROJECT ORGANIZATION	14
CHAPTER 2	
2.1 RASPBERRY PI DEVELOPMENT BOARD	15
2.2 SYSPIN CONFIGURATION AND GEATURES OF THE PI	19
2.3 I ² C	22
CHAPTER 3	
3.1 BASIC ARCHITECTURE	23
3.2 SYSTEM DESIGN	24
3.3 DIGITAL DC MOTOR CONTROL AND PWM	26
3.4 COMPLETE SMART HOME CONTROL SYSTEM	28
3.5 ALGORITHM AND PROGRAMMING	32
CHAPTER 4	
4.1 ACCOMPLISHMENTS	36
4.2 RESULTS AND PERFORMANCE	36
4.3 DISCUSSION AND CONCLUSION	37
4.4 FUTURE WORK	39
REFERENCES	45

CHAPTER 1: INTRODUCTION

1.1 INTRODUCTION

A Smart Home is one that provides its home owners comfort, security, energy efficiency (low operating costs) and convenience at all times, regardless of whether anyone is home. The technology and development of such a system is known as 'domotics'.

"Smart Home" is the term commonly used to define a residence that has appliances, lighting, heating, air conditioning, TVs, computers, entertainment audio & video systems, security, and camera systems that are capable of communicating with one another and can be controlled remotely by a time schedule, from any room in the home, as well as remotely from any location in the world by phone or internet.

Installation of smart products give the home and its occupants various benefits — the same benefits that technology and personal computing have brought to us over the past 30 years — convenience and savings of time, money and energy.

Most homes do not have these appliances and systems built into them, therefore the most common and affordable approach is for the home owner to retrofit smart products into their own finished home.

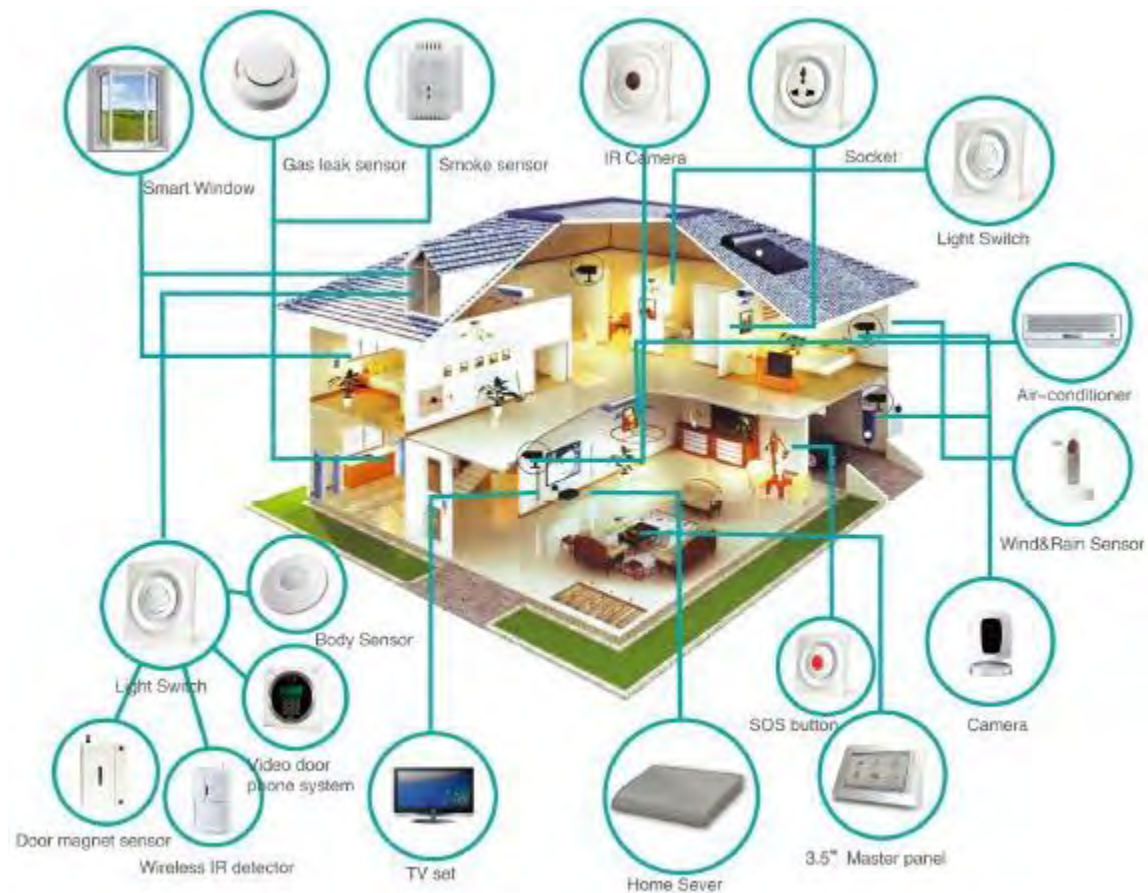


Figure 1 A modern day Smart Home setup

Products are available in a variety of protocols, i.e. the means of communication between themselves, and are mostly compatible with the internet, tablet devices and cell phones. These include protocols like X10, Z-Wave, UPB (Universal Powerline Bus) and EnOcean. Products that use the same protocol offer the ability to add products and hardware at the homeowners' own pace and budget. The system can grow to meet the needs of a changing family as time goes on. All of these products can be selected from various manufacturers, preventing an expensive obsolescence or non-competitive pricing.

An emerging important feature of a smart home is conservation of the earth's limited resources. More and more people are becoming aware of the ability to make their homes truly smart and green by utilizing home controllers integrated with all home sub-systems to increase savings by controlling lighting, window coverings, HVAC, irrigation and by monitoring usage. Many home controllers have built-in monitoring systems whereby they calculate and log usage by all connected devices, giving the home owner heightened awareness and the knowledge to make changes as necessary. These systems can even be accessed over the Internet from anywhere in the world so the homeowner can adjust consumption anytime, anywhere.

1.2 LITERATURE REVIEW

The first smart homes were ideas, not actual structures. For decades, science fiction has explored the idea of home automation. Prolific writers, such as Ray Bradbury, imagined a future where homes were interactive, and seemingly ran themselves. In Bradbury's cautionary short story, "There Will Come Soft Rains" he describes an automated home that continues to function even after humans have died out. It's all well and frightening, until you consider the actual benefits of home automation, and then the idea becomes more comforting than chilling. Although the idea of home automation has been around for some time, actual smart homes have only existed a short while.

By 1920, home appliances were a common sight in most households. Although home appliances aren't what we'd consider "smart," they were an incredible achievement in the early twentieth century. These achievements began with the first engine-powered vacuum cleaner in 1901. A more practical electricity-powered vacuum was invented in 1907. Within twenty years, refrigerators would be invented, as well as

clothes dryers, washing machines, irons, toasters, and many other items. Although it was never commercially sold, the ECHO IV was the first smart device, made in 1966. This clever device could compute shopping lists, control the home's temperature and turn appliances on and off. The Kitchen Computer, developed a year later, could store recipes. These two devices were the first of what came to be known as a 'home computer'.

From 1998, smart homes, or home automation, began to increase in popularity all the way to the early 2000s. As such, different technology began to emerge. Smart homes suddenly became a more affordable option, and therefore a viable technology for consumers. Domestic technologies, home networking, and other gadgets began to appear in the market.

Today's smart homes are more about security and living greener. Our smart homes are sustainable, and they help to ensure that our homes aren't expending unnecessary energy. They also help alert us to intruders (whether we're home or not). Current trends in home automation include remote mobile control, automated lights, automated thermostat adjustment, scheduling appliances, mobile/email/text notifications, and remote video surveillance. Connectivity and interactivity are driving the way families live and manage their homes. So, while we are expected to be in more places due to business travel or social activities, these new smart systems provide cutting edge connectivity to our household, even when we are far away. And when the house is occupied, the high level of automation enables more convenience, control and safety from any part of your property. It all adds up to fewer worries and increased enjoyment of life, which is something we would all welcome

INSIDE BILL GATES' HOME

Microsoft Chairman Bill Gates' home just outside of Seattle, Wash., might be the most famous smart home to date. Everyone in the home is pinned with an electronic tracking chip. As you move through the rooms, lights come on ahead of you and fade behind you. Your favorite songs will follow you throughout the house, as will whatever you're watching on television. You can entertain yourself by looking at Gates' extensive electronic collection of still images, all available on demand. The chip keeps track of all that you do and makes adjustments as it learns your preferences. When two different chips enter the same room, the system tries to compromise on something that both people will like.

Figure 2 Bill Gates' home is considered to be one of the smartest in the world

HOW SMART HOMES WORK

Any device in your home that uses electricity can be put on your home network and at your command.

Whether you give that command by voice, remote control, tablet or smartphone, the home reacts. Most applications relate to lighting, home security, home theater and entertainment, and thermostat regulation. Although it might seem that one needs to spend a fortune to automate their home like Bill Gates, who spent more than \$100 million building his smart home, smart homes and home automation are becoming more common and affordable. Much of this is due to the rapid success of smartphones and tablet computers. Their constant Internet connections means they can be configured to control many other online devices.

The Internet of Things refers to the objects and products that are interconnected and identifiable through digital networks. This web-like sprawl of products is getting bigger and better every day. All of

the electronics in your home are fair game for this tech revolution, from your clock to your bathroom appliances.

All the appliances and devices are receivers, and the means of controlling the system, such as remote controls or keypads, are transmitters. If you want to turn off a lamp in another room, the transmitter will issue a message in numerical code that includes the following:

1. An alert to the system that it's issuing a command,
2. An identifying unit number for the device that should receive the command and
3. A code that contains the actual command, such as "turn off."

The very first home automation systems relied on communicating over electrical lines, which was not always reliable because the lines pick up noise from powering other devices. New systems use radio waves to communicate using the concept of mesh networks, meaning there is more than one way for the message to get to its destination.

Using a wireless network provides more flexibility for placing devices, but like electrical lines, they might have interference. Some protocols offer a way for your home network to communicate over both electrical wires and radio waves, making it a dual-mesh network. If the message isn't getting through on one platform, it will try the other.

In designing a smart home, one can do as much or as little home automation as desired. Here are some common things a home user can control using a home automation system:

- Cameras to track your home's exterior.
- Control a thermostat from your bed, the airport, anywhere your smartphone has a signal.
- LED lights let you program color and brightness right from your smartphone.

- Motion sensors will send an alert when there's motion around your house, and they can even tell the difference between pets and burglars.
- Smartphone integration lets you turn lights and appliances on or off from your mobile device.
- Door locks and garage doors can open automatically as your smartphone approaches.
- Auto alerts from your security system will immediately go to your smartphone, so you instantly know if there's a problem at home.

ADVANTAGES

Smart homes may make life easier and more convenient. Whether you're at work or on vacation, the smart home will alert you to what's going on, and security systems can be built to provide an immense amount of help in an emergency. For example, not only would a resident be woken with notification of a fire alarm, the smart home would also unlock doors, dial the fire department and light the path to safety. Smart homes also provide some energy efficiency savings. Electric bills go down when lights are automatically turned off in empty rooms, and rooms can be heated or cooled based on who is there at any given moment. Some devices can track how much energy each appliance is using and command power hogs to use less.

The technology promises tremendous benefits for elderly people living alone. A smart home could notify the resident when it's time to take medicine, alert the hospital if the resident falls and track how much the resident is eating. If an elderly person is a little forgetful, the smart home could perform tasks such as shutting off the water before a tub overflow or turning off the oven if the cook had wandered away. It also allows adult children who might live elsewhere to participate in the care of their aging parent. Easy-to-control automated systems would provide similar benefits to those with disabilities or a limited range of movement.

DRAWBACKS

A smart home probably sounds like a nightmare to those people not comfortable with computers. One of the primary mental blocks of installing a smart home system is balancing the complexity of the system against the usability of the system. If it's downright exasperating, then it's actually making your life harder instead of easier. When planning the system, it's important to consider a number of factors like components and devices to be used, intuitiveness to new or non-users, number of people accessing the system, addressing maintenance issues and failures, and the ease of use of interface.

1.3 OBJECTIVE

My objective of this project is to successfully design and implement a low-cost home automation system which is easy to use and scalable to large numbers of connected devices. I plan on using LED lights and motor to represent the regular lights we use in our homes and offices, and a motor to represent the fans. I will use a Raspberry Pi and other various components that can be easily accessed in order to put the whole setup together. This approach will give me a fair idea of how to power, control and manage the individual components from the central hub. Due to the drawbacks of designing smart home systems, some of which are discussed above, I realized it may be easier to start with a very basic home network and expand as enhancements are needed or desired. Like many new technologies, smart

homes require a significant investment in both cash and time to keep up. Therefore, my approach to this project was to design the simplest possible set-up at first, then keep on adding additional features while keeping in mind the costs and ease of use.

1.4 PROJECT ORGANIZATION

I designed the project to be low-cost, effective, reliable and simple to use. Chapter 1 consists of the overview of home automation and work done on it for commercialization till now. In Chapter 2, I have discussed the Raspberry Pi, which is going to act as the hub for my proposed design. Chapter 3 contains discussions about the design of my proposed system along with its architecture and algorithms used. Chapter 4 contains the results of my designed system and its performance, along with further work that I intend to do in order to develop the system.

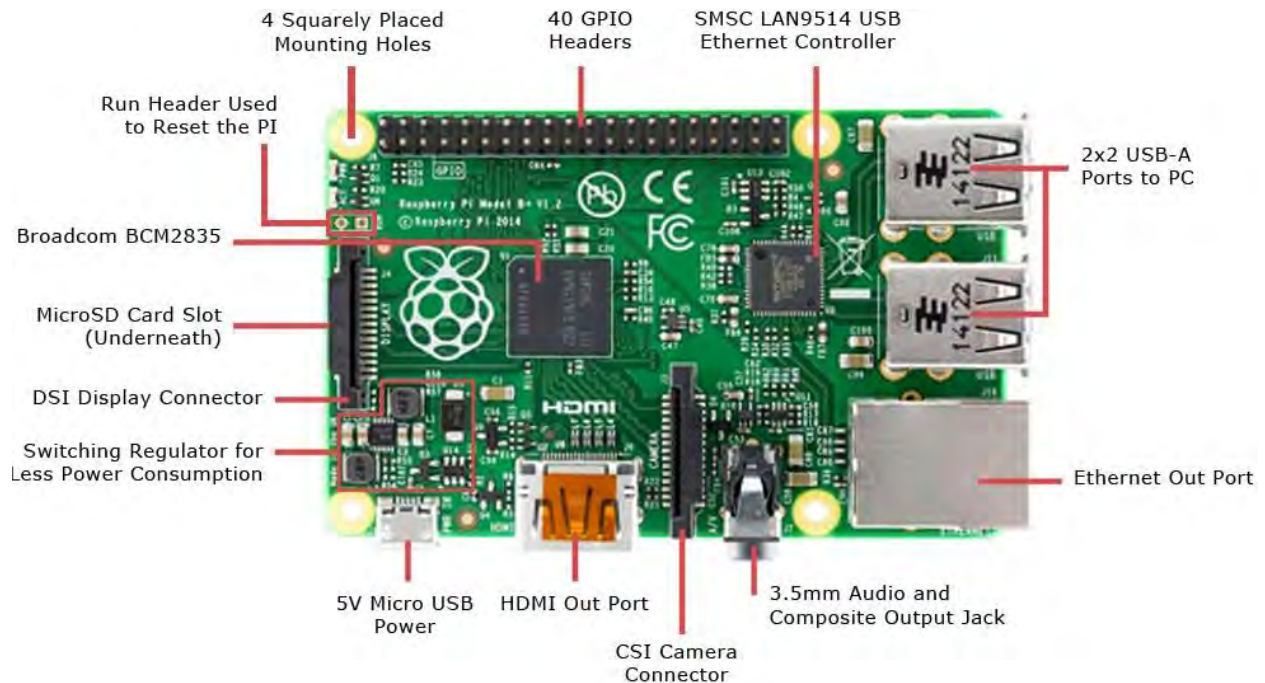
CHAPTER 2: THE RASPBERRY PI

2.1 RASPBERRY PI DEVELOPMENT BOARD

For my project, I found that the Raspberry Pi was most suited among the usual development boards that are available on the market today.

The Raspberry Pi is a series of small single-board computers developed in the United Kingdom by the Raspberry Pi Foundation to promote the teaching of basic computer science in schools and in developing countries.

I used a Raspberry Pi 3 Model B+. This fully functional computer has a lot more computing power and built-in libraries to implement different future aspects of home automation. It can be wirelessly connected to the home network, therefore is able to control aspects of smart home appliances fairly easily. It has 40 General Purpose Input Output (GPIO) pins to connect a variety of components to itself directly via. wired connections.



Increased noise immunity is a benefit of choosing PWM over analog control, and is the principal reason PWM is sometimes used for communication. Switching from an analog signal to PWM can increase the length of a communications channel dramatically. At the receiving end, a suitable RC (resistor-capacitor) or LC (inductor-capacitor) network can remove the modulating high frequency square wave and return the signal to analog form.

The GPU provides Open GL ES 2.0, hardware-accelerated Open VG, and 1080p30 H.264 high-profile decode and is capable of 1Gpixel/s, 1.5Gtexel/s or 24 GFLOPs of general purpose compute. This means that if one plugs the Raspberry Pi 3 into their HDTV, they could watch Blu-ray quality video, using H.264 at 40MBits/s.

The biggest change that has been enacted with the Raspberry Pi 3 is an upgrade to a next generation main processor and improved connectivity with Bluetooth Low Energy (BLE) and BCM43143 Wi-Fi on board. Additionally, the Raspberry Pi 3 has improved power management, with an upgraded switched power source up to 2.5 Amps, to support more powerful external USB devices.

The main differences are the quad core 64-bit CPU and on-board Wi-Fi and Bluetooth. The RAM remains 1GB and there is no change to the USB or Ethernet ports. However, the upgraded power management should mean the Pi 3 can make use of more power-hungry USB devices. For Raspberry Pi 3, Broadcom have supported us with a new SoC, BCM2837. This retains the same basic architecture as its predecessors BCM2835 and BCM2836, so all those projects and tutorials which rely on the precise details of the Raspberry Pi hardware will continue to work. The 900MHz 32-bit quad-core ARM CortexA7 CPU complex has been replaced by a custom-hardened 1.2GHz 64-bit quad-core ARM Cortex-A53. In terms of size it is identical to the B+ and Pi 2. All the connectors and mounting holes are in the same place so all existing add-ons, HATs and cases should fit just fine although the power and activity LEDs have moved to make room for the Wi-Fi antenna. The performance of the Pi 3 is roughly 50-60% faster than the Pi 2 which means it is ten times faster than the original Pi. All of the connectors are in the same place and have the same functionality, and the board can still be run from a 5V micro-USB power adapter. This time round, we're recommending a 2.5A adapter if you want to connect power-hungry USB devices to the Raspberry Pi.

The Raspberry Pi 3's four built-in USB ports provide enough connectivity for a mouse, keyboard, or anything else that you feel the RPi needs, but if you want to add even more you can still use a USB hub. Keep in mind, it is recommended that you use a powered hub so as not to overtax the on-board voltage regulator. Powering the Raspberry Pi 3 is easy, just plug any USB power supply into the micro-USB port. There's no power button so the Pi will begin to boot as soon as power is applied, to turn it off simply

remove power. The four built-in USB ports can even output up to 1.2A enabling you to connect more power-hungry USB devices (This does require a 2Amp micro USB Power Supply).

On top of all that, the low-level peripherals on the Pi make it great for hardware hacking. The 0.1" spaced 40-pin GPIO header on the Pi gives you access to 27 GPIO, UART, I 2C, SPI as well as 3.3 and 5V sources. Each pin on the GPIO header is identical to its predecessor the Model B+.

2.2 PIN CONFIGURATION AND FEATURES OF THE PI

PULSE WIDTH MODULATION (PWM)

One of the most important features of the Pi is the Pulse Width Modulation pins. Pulse Width Modulation, or PWM, is a technique for getting analog results with digital means. Digital control is used to create a square wave, a signal switched between on and off. This on-off pattern can simulate voltages in between full on (5 Volts) and off (0 Volts) by changing the portion of the time the signal spends on versus the time that the signal spends off. The duration of "on time" is called the pulse width. To get varying analog values, we change, or modulate, that pulse width. The duty cycle is the percent of time that a signal is 'ON' with respect to the time period of the signal.

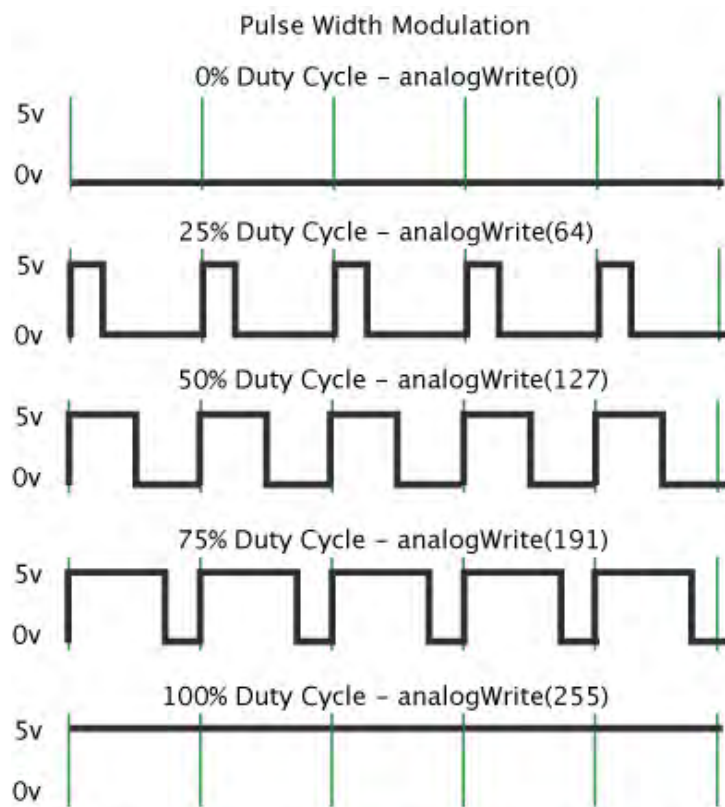


Figure 3 Pulse Width Modulation

One of the advantages of PWM is that the signal remains digital all the way from the processor to the controlled system; no digital-to-analog conversion is necessary. By keeping the signal digital, noise effects are minimized. Noise can only affect a digital signal if it is strong enough to change a logical-1 to a logical-0, or vice versa.

Increased noise immunity is yet another benefit of choosing PWM over analog control, and is the principal reason PWM is sometimes used for communication. Switching from an analog signal to PWM can increase the length of a communications channel dramatically. At the receiving end, a suitable RC (resistor-capacitor) or LC (inductor-capacitor) network can remove the modulating high frequency square wave and return the signal to analog form.

GPIO

The Raspberry Pi 3 features the same 40-pin general-purpose input-output (GPIO) header as all the Pis going back to the Model B+ and Model A+. Any existing GPIO hardware will work without modification; the only change is a switch to which UART is exposed on the GPIO's pins, but that's handled internally by the operating system.

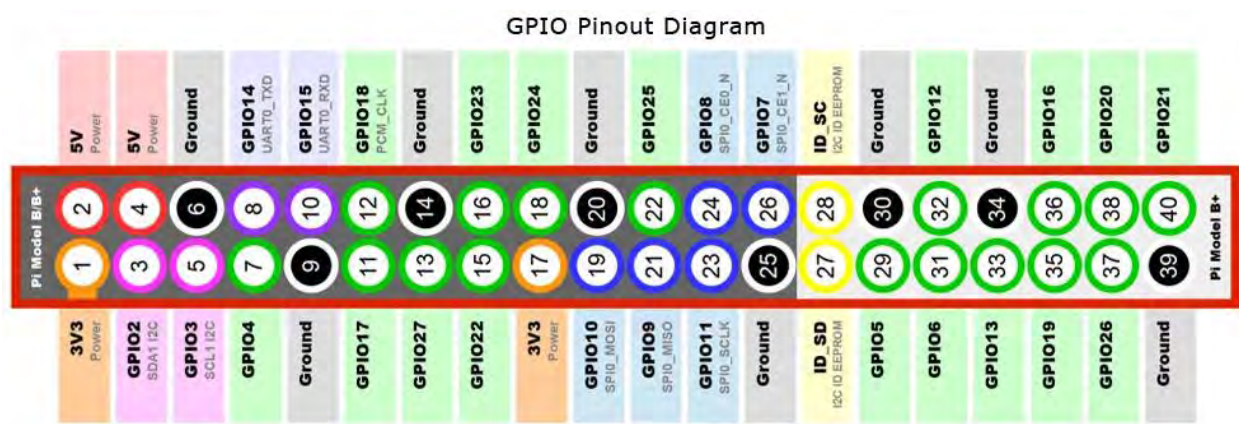


Figure 4 Pin Diagram for the Pi 3 Model B+

SOC

Built specifically for the new Pi 3, the Broadcom BCM2837 system-on-chip (SoC) includes four high-performance ARM Cortex-A53 processing cores running at 1.2GHz with 32kB Level 1 and 512kB Level 2 cache memory, a VideoCore IV graphics processor, and is linked to a 1GB LPDDR2 memory module on the rear of the board.

USB CHIP

The Raspberry Pi 3 shares the same SMSC LAN9514 chip as its predecessor, the Raspberry Pi 2, adding 10/100 Ethernet connectivity and four USB channels to the board. As before, the SMSC chip connects to the SoC via a single USB channel, acting as a USB-to-Ethernet adaptor and USB hub.

ANTENNA

There's no need to connect an external antenna to the Raspberry Pi 3. Its radios are connected to this chip antenna soldered directly to the board, in order to keep the size of the device to a minimum. Despite its diminutive stature, this antenna should be more than capable of picking up wireless LAN and Bluetooth signals – even through walls.

2.3 I²C

I²C is a serial protocol for two-wire interface to connect low-speed devices like microcontrollers, EEPROMs, A/D and D/A converters, I/O interfaces and other similar peripherals in embedded systems. It was invented by Philips and now it is used by almost all major IC manufacturers. I²C bus is popular because it is simple to use, there can be more than one master, only upper bus speed is defined and only two wires with pull-up resistors are needed to connect almost unlimited number of I²C devices. I²C can use even slower microcontrollers with general-purpose I/O pins since they only need to generate correct 'Start and Stop' conditions in addition to functions for reading and writing a byte.

Each slave device has a unique address. Transfer from and to master device is serial and it is split into 8-bit packets. All these simple requirements make it very simple to implement I²C interface even with cheap microcontrollers that have no special I²C hardware controller. One only needs 2 free I/O pins and few simple I²C routines to send and receive commands.

The Raspberry Pi only has 40 GPIO pins. Some of them are taken to power the device and other peripherals, leaving us with even fewer pins. Therefore, I²C is quite essential to connect more devices to the Pi when there are no further pins left. This contributes to the robustness of the whole setup.

CHAPTER 3: SYSTEM DESIGN AND DEVELOPMENT

3.1 BASIC ARCHITECTURE

In this section, I will highlight the hardware used for the completion of the system, based on different segments of the overall system and the functions it will be responsible for. One possible approach of designing the system is that there is a central hub or device connected to your smartphone, tablet, touchscreen, etc. It will primarily be responsible as the central control unit.

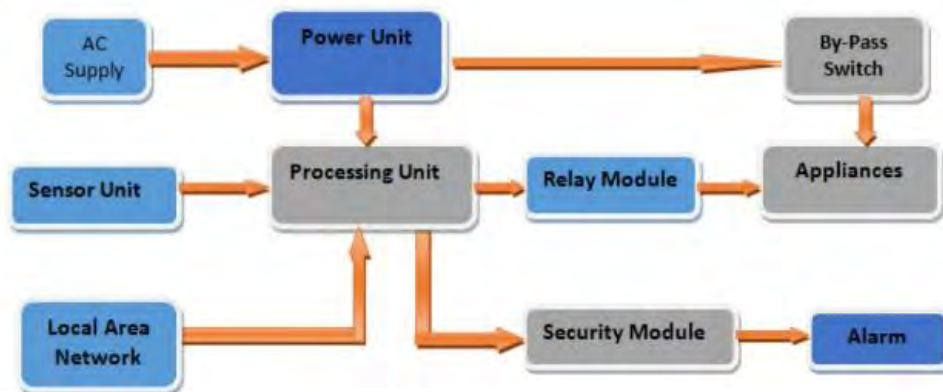


Figure 5 System Architecture Block Diagram

The above figure shows the basic features of my system, and some extra features that I would like to work with in future in order to expand and improve on the features of the overall system. Details about the security system and other further possibilities will be discussed later in the paper. I downloaded a free mobile application to control the Pi wirelessly. The Pi can also be controlled via. a display and keyboard interface, or using a touchscreen especially available for the Pi. For now, the commands to the Pi were made using a keyboard, but that can be easily replaced with a touchscreen LCD module.

3.2 SYSTEM DESIGN

I used a relay to act as the primary switch that would control the peripherals connected to the Pi. A relay is usually an electromechanical device that is actuated by an electrical current. The current flowing in one circuit causes the opening or closing of another circuit. Relays are like remote control switches and are used in many applications because of their relative simplicity, long life, and proven high reliability. Relays are used in a wide variety of applications throughout industry, such as in telephone exchanges, digital computers and automation systems. Highly sophisticated relays are utilized to protect electric power systems against trouble and power blackouts as well as to regulate and control the generation and distribution of power. In the home, relays are used in refrigerators, washing machines and dishwashers, and heating and air-conditioning controls. Although relays are generally associated with electrical circuitry, there are many other types, such as pneumatic and hydraulic. Input may be electrical and output directly mechanical, or vice versa.

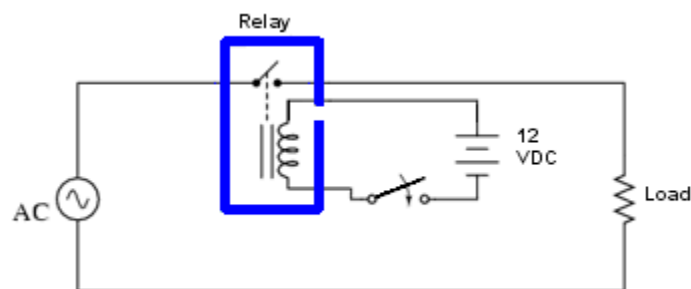


Figure 6 Internal Mechanism of a Relay

All relays contain a sensing unit, the electric coil, which is powered by AC or DC current. When the applied current or voltage exceeds a threshold value, the coil activates the armature, which operates either to close the open contacts or to open the closed contacts. When a power is supplied to the coil, it generates a magnetic force that actuates the switch mechanism. The magnetic force is, in effect, relaying the action from one circuit to another. The first circuit is called the control circuit; the second is called the load circuit. I used a simple relay purchased from TechShopBD. It has four channels, i.e. can operate four separate devices.



Figure 7 4 Channel 5V Relay Module

A 9V DC motor was used to model as a 'fan' that would be used normally at a user's home. The speed of the motor would be remotely varied, just like you would be able to do with the speed of your fan when this device is implemented.



Figure 8 DC Motor

3.3 DIGITAL DC MOTOR CONTROL AND PWM

A motor controller was needed to implement the PWM ability of the Raspberry Pi. A motor controller is a device or group of devices that serves to govern in some predetermined manner the performance of an electric motor.^[1] A motor controller might include a manual or automatic means for starting and stopping the motor, selecting forward or reverse rotation, selecting and regulating the speed, regulating or limiting the torque, and protecting against overloads and faults.

Every electric motor has to have some sort of controller. The motor controller will have differing features and complexity depending on the task that the motor will be performing. The simplest case is a switch to connect a motor to a power source, such as in small appliances or power tools. The switch may be manually operated or may be a relay or contactor connected to some form of sensor to automatically start and stop the motor. The switch may have several positions to select different connections of the motor. This may allow reduced-voltage starting of the motor, reversing control or

selection of multiple speeds. Overload and over current protection may be omitted in very small motor controllers, which rely on the supplying circuit to have over current protection. Small motors may have built-in overload devices to automatically open the circuit on overload. Larger motors have a protective overload relay or temperature sensing relay included in the controller and fuses or circuit breakers for over current protection. An automatic motor controller may also include limit switches or other devices to protect the driven machinery.

More complex motor controllers may be used to accurately control the speed and torque of the connected motor (or motors) and may be part of closed loop control systems for precise positioning of a driven machine.

The L298 motor controller was used for controlling the speed of the DC motor, which would model as a 'fan'.

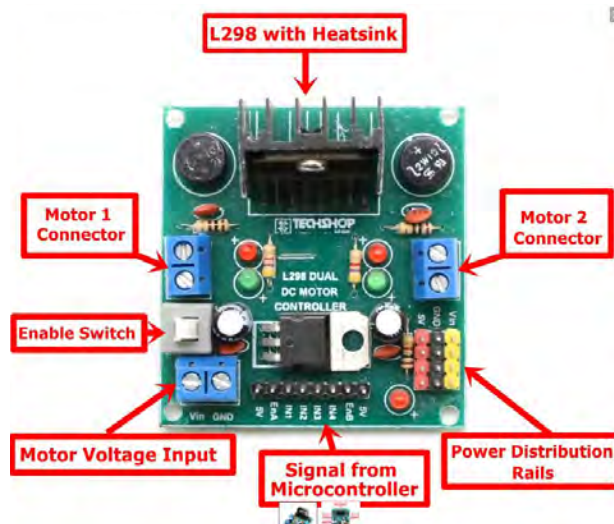


Figure 9 Motor Controller

3.4 COMPLETE SMART HOME CONTROL SYSTEM

The lights get their own power in reality, from the mains supply. The relay just acts as a switch to turn it on or off. The power to the fan comes from the motor controller, and is routed through a relay, which acts as a switch to turn the fan on or off.

The motor controller is needed to control PWM of the motor, which in turn will control the speed of the motor. The EN A pin of the controller is connected to the PWM pin 32 of the Pi. The duty cycle of the signal being sent to the motor from the motor controller is controlled between 0 to 100%. The motor speed has 5 modes, starting from 0 to 4, with 4 being full speed.

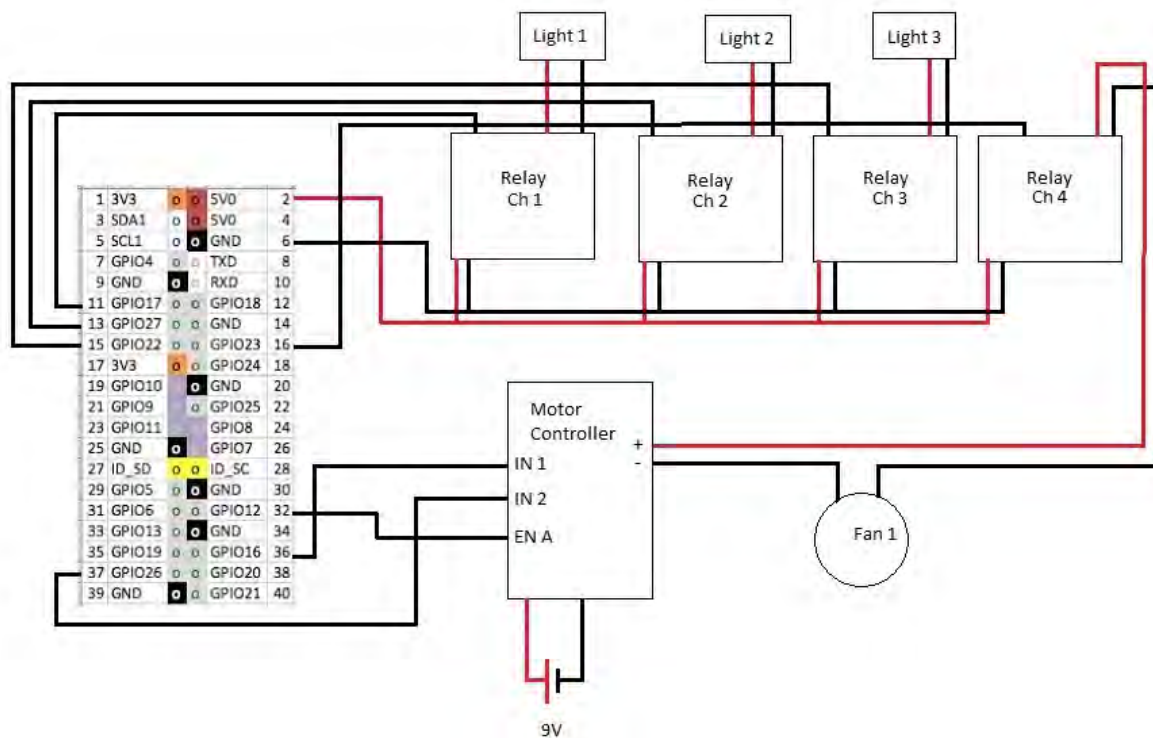


Figure 10 Schematics of the whole system



Figure 11 Connections to the Pi

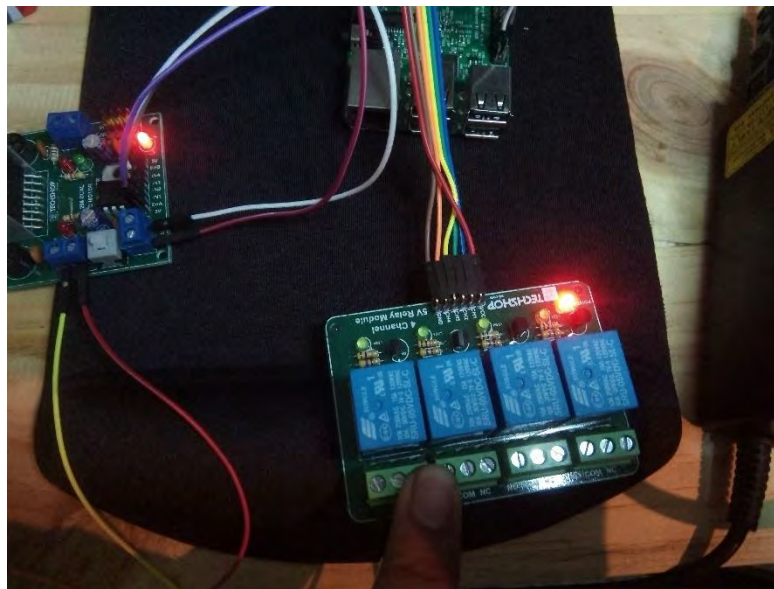


Figure 12 Relay Powered Up

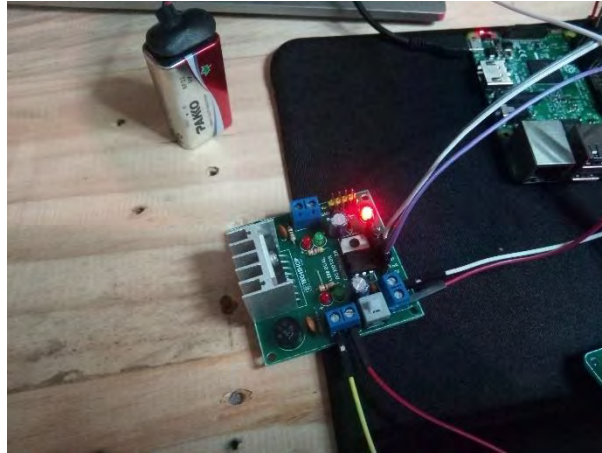


Figure 13 Motor Controller with Connections

For this model, the relay is powered from a 5V source from the Pi. This is not a problem, as the relay itself uses moderate levels of current. The relay in question can actually handle devices connected from the main line, but it is better to buy slightly more expensive relays for safety purposes. The motor controller is powered using an external 9V battery. This will also supply power to the motor. The power line going to the motor passes through channel 4 of the relay, in order to turn the motor on and off. The

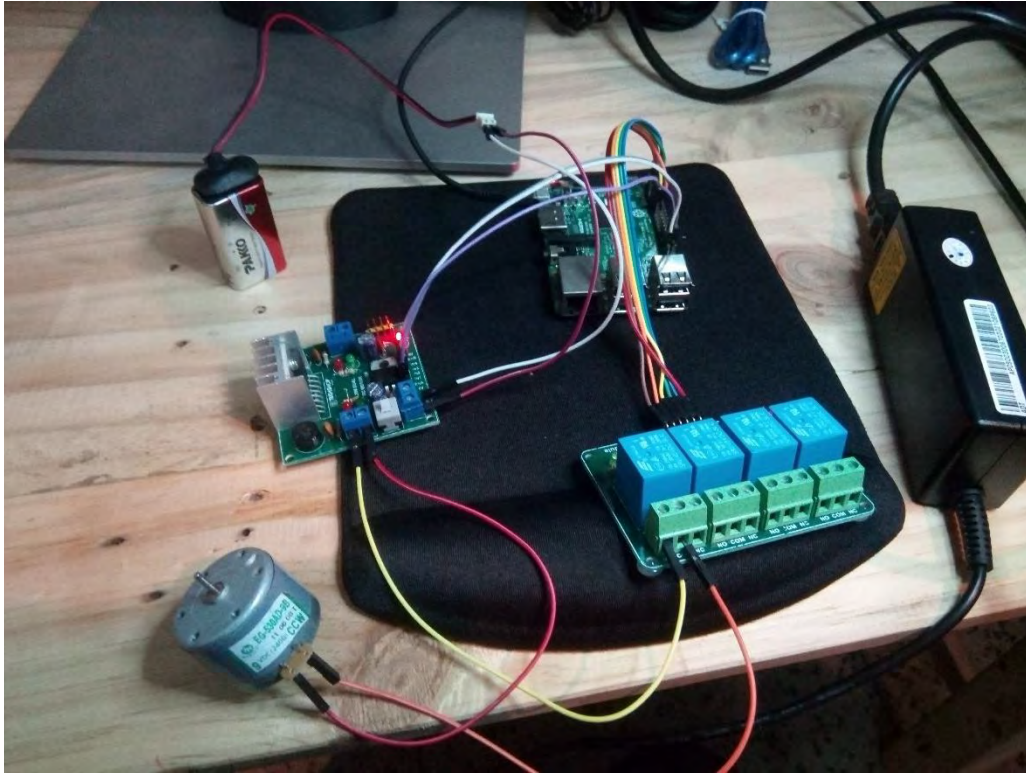


Figure 14 Fully Connected System

Raspberry Pi is powered from the mains using an adaptor. During the demonstration, channels 1 to 3 are modelled to be connected to 3 different lights. In real life, it could have just as easily been connected to any other appliance which needs to be remotely turned on or off.

3.5 ALGORITHMS AND PROGRAMMING

The algorithm was implemented in Python, using the Raspberry Pi's prepackaged programming environment.

```
import RPi.GPIO as GPIO

device_1 = 11
device_2 = 13
device_3 = 15
device_4 = 16
status_1 = False
status_2 = False
status_3 = False
status_4 = False
motor_pin_1 = 36
motor_pin_2 = 37
pwm_pin = 32
speed = 0

GPIO.setmode(GPIO.BOARD)
GPIO.setup(device_1, GPIO.OUT)
GPIO.setup(device_2, GPIO.OUT)
GPIO.setup(device_3, GPIO.OUT)
GPIO.setup(device_4, GPIO.OUT)
GPIO.setup(motor_pin_1, GPIO.OUT)
GPIO.setup(motor_pin_2, GPIO.OUT)
GPIO.setup(pwm_pin, GPIO.OUT)

p = GPIO.PWM(32, 50)
```

```

while True:

choice = input("Please enter 1 to control light, 2 for fans. Press 0 to turn off all devices")

if choice == 1:

while True:

if status_1 is True:

    print("Light 1 is on")

else:

    print("Light 1 is off")

if status_2 is True:

    print("Light 2 is on")

else:

    print("Light 2 is off")

if status_3 is True:

    print("Light 3 is on")

else:

    print("Light 3 is off")


light_choice = input("Please enter 1 to toggle light 1, 2 to toggle light 2, 3 to toggle light 3, 0 to
return")

if light_choice == 1:

    status_1 = not status_1
    GPIO.output(device_1, status_1)

elif light_choice == 2:

    status_2 = not status_2
    GPIO.output(device_2, status_2)

elif light_choice == 3:

    status_3 = not status_3
    GPIO.output(device_3, status_3)

elif light_choice == 0:

    break

elif choice == 2:

```

while True:

if status_4 is True:

print("Fan is on")

elif status_4 is False:

print("Fan is off")

fan_choice = input("Please enter 1 to toggle fan on and off, 2 to control fan speed, 3 to see current fan speed, 0 to return")

if fan_choice == 1:

p.start(1)
speed = 60
p.ChangeDutyCycle(speed)
GPIO.output(36, True)
GPIO.output(37, False)
status_4 = not status_4
GPIO.output(device_4, status_4)

elif fan_choice == 2:

while True:
speed_choice = input("Select fan speed from 1 to 4, 0 to return")
p.start(1)
if speed_choice == 1:
speed = 20
p.ChangeDutyCycle(speed)
GPIO.output(36, True)
GPIO.output(37, False)
elif speed_choice == 2:
speed = 40
p.ChangeDutyCycle(speed)
GPIO.output(36, True)
GPIO.output(37, False)
elif speed_choice == 3:
speed = 60
p.ChangeDutyCycle(speed)
GPIO.output(36, True)
GPIO.output(37, False)
elif speed_choice == 4:
speed = 80
p.ChangeDutyCycle(speed)
GPIO.output(36, True)
GPIO.output(37, False)
elif speed_choice == 0:
break

elif fan_choice == 3:

```

    if speed == 20:
        print("Fan speed is 1")
    elif speed == 40:
        print("Fan speed is 2")
    elif speed == 60:
        print("Fan speed is 3")
    elif speed == 80:
        print("Fan speed is 4")

elif fan_choice == 0:
    break

elif choice == 0:
    GPIO.output(device_1, False)
    GPIO.output(device_2, False)
    GPIO.output(device_3, False)
    GPIO.output(device_4, False)
    p.stop()

GPIO.cleanup()

break

```

CHAPTER 4: RESULTS AND DISCUSSION

4.1 ACCOMPLISHMENTS

I was able to successfully design and implement the system that I set out to accomplish. The design is simple and easy to use. The hardware was also easy to acquire over the internet. It was also possible for me to design the algorithm in a simplistic manner, which led the system to be robust. With pulse width modulation, I implemented a way to control the speed of the 'fan' as well. Although there were some issues with supplying power to the individual components of the system, I was able to overcome them either by isolating the components and pairing them with separate power supplies, or using devices designed to consume low power.

4.2 RESULTS AND PERFORMANCE

A significant time was used to put both the hardware and software through its paces in order to reveal and hidden flaws. Endless loops of the algorithm were run in a simulated environment, and there was no theoretical or mathematical possibility of an error occurring which would result in the termination of the program. The Pi is calculated to consume very little power, therefore can be easily connected to a power reserve system like a backup generator or even simply an UPS. In case of remote locations where it will be difficult wired power sources to reach the Pi, it is also tested to have run on 9V batteries. Therefore,

the system is set to be highly mobile in terms of hub location. In case of a power failure, the Pi can be programmed to start automatically and continue to function as soon as power is restored.

The hardware setup did not show any major problems. The motor, if running for prolonged periods of time, may get fairly hot, but nothing serious. In practical use, all running components will increase in temperature. This may lead to an increase in the amount of current being drawn by each device.

However, this is not a problem, as the power for the major devices will be provided from the main line, and not from the Pi, thus reducing the chances of overloading the computer system.

4.3 DISCUSSION AND CONCLUSION

In this research, I was able to establish a fully functioning replica of a home automated system. Due to the simplicity of the design, more feedback mechanisms (thermistors, LRD, temperature sensors, etc.) can be added to the system in order to increase the degree of automation and user preference.

The basic system can be implemented in a real home for as low as BDT. 6,000. Other features can be readily added to the system. The costs associated would decrease marginally as more and more devices are added, because the most expensive device used by far is the Raspberry Pi. Slightly better-quality devices, which would be highly recommended, would cost around BDT 10,000 for the basic setup to control light, fan, fan speed, and some other basic appliances.

The basic system proposed use of a Raspberry Pi computer to act as a hub for controlling other connected devices, such as lights, fans, security cameras, etc. A scale model was designed and made using LEDs and motors to represent lights and fans respectively. Due to the robustness of the system design, scalability is not an issue, therefore this design can be implemented for real lights and fans that

we generally use in our homes. The simplistic design and implementation helped it to run without any software glitches or bugs. A significant time was used to put both the hardware and software through its paces in order to reveal and hidden flaws. There were no mentionable problems detected in the mock-up model. However, it is not possible to absolutely guarantee that the system will be absolutely problem-free when put to real life applications. Therefore, further testing with actual devices is recommended.

The system is designed to be fairly easy to use. The same algorithms and I/O can be used in the actual device itself. Input is based on numbers with specific instructions, similar to how people interact with their network operators in their mobile phones while purchasing internet packages, inquiring about rates, etc. As people are already familiar with this method of I/O, there will be little for them to get adjusted to the user interface. It was not possible to overload the interface or put the Pi into any form of infinite loop (i.e. 'hang' the device). The algorithm was simple enough for the Pi to efficiently run it.

The testing has proven the system to be efficient and user-friendly as well as robust. The algorithm can be easily manipulated to add further devices as necessary. I²C can be used to increase the number of ports available to the user to increase the number of connected devices. It is also possible to connect devices wirelessly over the Wi-Fi network to the Pi with the help of a cloud server.

4.4 FUTURE WORK

The demonstrated small-scale model is used to show that it is fairly easy to automate the components of a regular home using existing technology. Due to lack of time, only the basic operations were set up. However, it is possible to expand and implement a vast number of multifunctional devices on this setup. Some features that can be added will be discussed.

Improved UI and Mobile Application

The user interface designed for the demonstration process is fairly simple and straightforward. The user only has to input a unique number displayed for a specific command that is displayed on the screen. For now, the Pi was wirelessly connected to a laptop, and commands were given using the laptop.



Figure 15 Touchscreen Module for the Pi

However, the Pi is capable of acting as a mobile platform, similar to that of a tablet or mobile phone, as long as it gets a source of power. External touchscreen display modules can be purchased so that users have similar experiences with the Pi compared to a mobile phone.

The coding was done using Python script. The commands have been designed and implemented to be as simple as possible. There are no complicated calculations or processes going on in the background. This means that the code can easily be implemented into any other scripts or platforms, making it readily possible for developers to create an open-source mobile application. Users will then have the option to just download the application on their device, and proceed.

Multiple Devices Connected using I²C

This feature of the Raspberry Pi will theoretically allow us to connect a large number of devices, much more than what could be done with the 40 existing GPIO pins that come with the Pi. Using I²C, multiple devices can be controlled with the same pin, as long as adequate power supply is provided and the current in the wires do not run too high. A solution to this is to command the devices one at a time, i.e. in series, therefore reducing the power consumption drastically, and making the I²C implementation more effective.

It is also possible to connect sonar detectors to the system in order to monitor the presence of individuals throughout the home, and adjust lighting, fan speed, etc. to their preferences. RFID trackers can also be placed on individuals for improved accuracy and identification.

Integrated Security System

Aspects of your home's security system can also be connected to the system. The Pi has a peripheral camera module that can be purchased and set up with the Pi. Motion detectors can be used to detect the presence of anyone on your front doorstep or strategic places around your home. The motion detectors will trigger the camera to take a picture of the person who came to visit while you were not at home. You can instantly be notified by an email or an app notification, along with the picture of the person in question.



Figure 16 Camera Module for Pi

Remote Operations and Automated Feedback Systems with NEST, Amazon Echo, Belkin WeMo and other devices

One of the most promising features of home automation is that not only can you remotely control aspects of your home, it is also possible to program your devices to carry out tasks in your absence. Projects like automatic pet feeding mechanisms, plant watering systems that monitor weather situations, etc. are fairly common with home automation systems. These could also be implemented into the demonstrated system. Washing machines will do your laundry automatically at given time frames, coffee makers will make coffee in the morning without your intervention. The possibilities and implementations are virtually endless.



Figure 17 Automated Pet Food Dispenser



Figure 17 Automated Plant Watering System

It was found that it is also possible to control other devices by NEST, Amazon, and smart devices by a whole range of manufacturers using the Raspberry Pi through a web server. This means that there is a variety of possibilities for integrating fully functional devices with the Pi. The addition of a web server will be a one-time investment in terms of both money and effort. Once fully established, it will be self-sustaining and will require almost no maintenance.

Voice Recognition with Artificial Intelligence

We are all familiar with mobile phone voice assistance applications like Siri, OK Google, Bixby, Cortana and Alexa. They exist not only to make communication with our devices easier, but carry out certain tasks on command as well. In the long run, it may be possible to implement an artificial home assistant to the fully constructed automation as well. Although I worked on designing a system of my own, there wasn't enough time to implement it in my project.

Instead of developing a fully independent system or software, I tried to use cloud computing facilities provided by Google and IBM Watson. The python has a built-in library for voice to text implementation, but it was not as stable or accurate as the ones by Google or IBM Watson. Both of these have a trial period for free, but after that one needs to pay for the services they use.

My main goal was to connect a USB microphone to the Pi, which would listen for commands from the user and upload the audio file in real time to the cloud computer. The output of this process would be a text file with the speech converted to text. The Pi could then analyze the text and carry out the command as needed. For the system to be very basic, the Pi would be programmed to analyze simple texts and search for words like 'FAN,' 'THREE,' and 'OFF.'

Implementing machine learning to this setup would also enable the system to understand and adopt to the needs of individual users, and is a long-term goal. Neural networks and machine learning would help the system to adjust to individual users by understanding their daily routines, needs and preferences.

REFERENCES

1. Alcantara, Jaclyn. "The Battle to Control Your Home." EC&M. Feb. 1, 2006. (Jan. 9, 2014)
http://ecmweb.com/mag/electric_battle_control_home
2. Atwell, Cabe. "Smart Home Systems are on the Rise." DesignNews.com. Dec. 31, 2013. (Jan. 9, 2014)
http://www.designnews.com/author.asp?section_id=1386&doc_id=270692&itc=dn_analysis_element&dfpPPParams=ind_182,industry_consumer,aid_270692&dfpLayout=blog
3. Atwell, Cabe. "Smart Power Strip Automates Appliances." DesignNews.com. Dec. 4, 2013. (Jan. 9, 2014) http://www.designnews.com/author.asp?section_id=1386&doc_id=270158
4. Burns, Matt. "Meet Revolv, the Missing Link to the Modern Smart Home." TechCrunch.com. Dec. 10, 2013. (Jan. 9, 2014) <http://techcrunch.com/2013/12/10/meet-revolv-the-missing-link-to-the-modern-smart-home/>
5. Cipriani, Jason. "Belkin WeMo Switch and Motion." Wired.com. Mar. 12, 2013. (Jan. 9, 2014)
<http://www.wired.com/reviews/2013/03/belkin-wemo/>
6. Covert, Adrian. "The Smart Home is a Pipe Dream." CNN Money. Jan. 2, 2014. (Jan. 9, 2014)
<http://money.cnn.com/2014/01/02/technology/innovation/ces-connected-home/>
7. Edmonds, Molly. "How Smart Homes Work" 25 March 2008.
HowStuffWorks.com. <<http://home.howstuffworks.com/smart-home.htm>> 1 April 2017
8. Gates, Bill. "The Road Ahead." Penguin Books. 1996.
9. Maxwell, Adrienne. "Understanding Home Automation." Modern Home Theater. February 2007
(Jan. 9, 2014)
http://www.modernhometheater.com/howto/home_automation_part1/index.html
10. McGlaun, Shane. "Lowe's Iris Smart Home Solution Aims for Simple Home Automation."
SlashGear.com. Jan. 6, 2014. (Jan. 9, 2014) <http://www.slashgear.com/lowes-iris-smart-home-solutions-aim-for-simple-home-automation-06311375/>
11. McKay, Hollie. "Home, Sweet Home: How to Talk to Your House." Fox News. Oct. 23, 2006. (Jan. 9, 2014) <http://www.foxnews.com/story/0,2933,224060,00.html>
12. Prindle, Drew. "Archos Spills the Beans on its Upcoming Lineup of Smart Home Devices Ahead of CES." Digitaltrends.com. Dec. 30, 2013. (Jan. 9, 2014)

<http://www.digitaltrends.com/home/archos-spills-beans-upcoming-lineup-smart-home-devices-ahead-ces/>

13. Ravindranath, Mohana. "Washington Area Tech Companies Join the 'Internet of Things' to Automate Homes." WashingtonPost.com. Jan. 6, 2014. (Jan. 9, 2014)
http://www.washingtonpost.com/business/on-it/washington-area-tech-companies-join-the-internet-of-things-to-automate-homes/2014/01/06/5a1ab5c4-73d6-11e3-8b3f-b1666705ca3b_story.html
14. Regan, Keith. "Ten Scary Things About Home Networks, Part 1." TechNewsWorld. Feb. 22, 2007. (Jan. 9, 2014) <http://www.technewsworld.com/story/55882.html>
15. Schory, Guy. "Smart Homes, the Human Aspect." Home Toys. April 2004. (Jan. 9, 2014)
<http://www.hometoys.com/htinews/apr04/articles/shorey/part2.htm>
16. SmartHome.com. Product Listings. (Jan. 9, 2014) http://www.smarthome.com/_/index.aspx
17. Snider, Mike. "Security Opens Door to Truly Connected Home." Courier Journal. Dec. 30, 2013. (Jan. 9, 2014) <http://www.courier-journal.com/usatoday/article/3890539>
18. Vanhemert, Kyle. "Your Jetsons Style Smart Home Starts with these Bluetooth Plugs." Wired.com. Jan. 3, 2014. (Jan. 9, 2014) <http://www.wired.com/design/2014/01/bluetooth-smart-plugs-control-your-house-depending-on-what-room-youre-in/>
19. Venkatesh, Alladi. "Smart Home Concepts: Current Trends." Center for Research on Information Technology and Organizations. July 1, 2003. (Jan. 9, 2014)
<http://repositories.cdlib.org/crito/home/377>
20. Wolf, Michael. "5 Smart Home Companies to Watch in 2014." Forbes.com. Dec. 31, 2014. (Jan. 9, 2014) <http://www.forbes.com/sites/michaelwolf/2013/12/31/5-smart-home-companies-to-watch-in-2014/>
21. Wollerton, Megan. "What We Loved and Hated about the 2013 Smart Home." CNET.com. Dec. 23, 2013. (Jan. 9, 2014) http://reviews.cnet.com/8301-17889_7-57615768/what-we-loved-and-hated-about-the-2013-smart-home/