

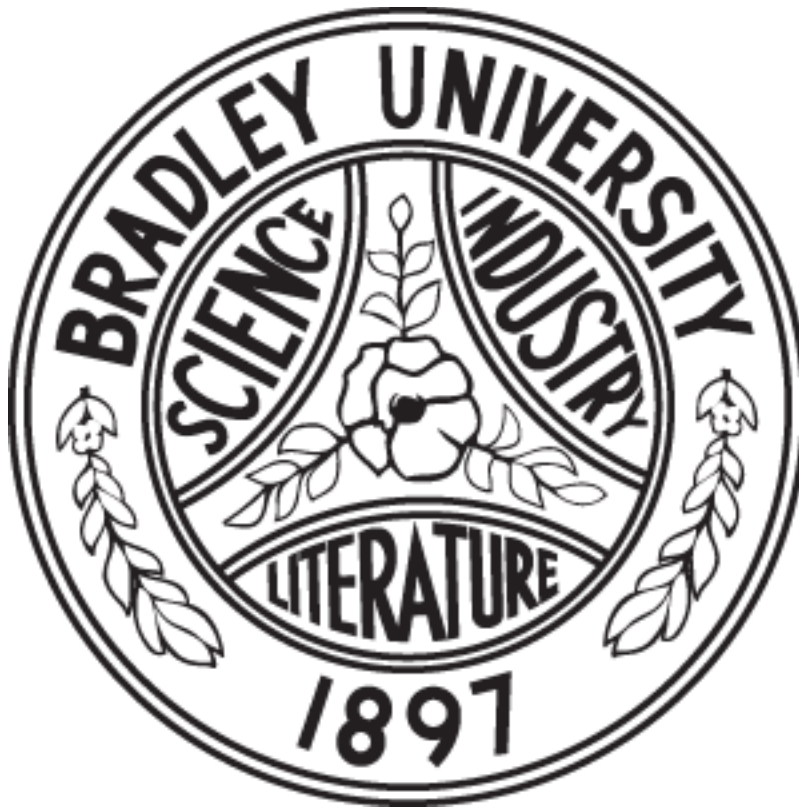
Smart Lighting System Project Proposal

Authors

Alex Berian , Dustin McCart

Client

Aleksander Malinowski



Bradley University
Department of Electrical Engineering

Date
October 15th, 2015

Executive Summary

Smart lighting is a growing industry for home automation. Many people are looking to join the home automation bandwagon, however it is a complicating and pricey task.

This project will result in a prototype for a smart light switch, to replace existing home light switches, that is easy to install. The smart lighting system will be controlled by not only button and switch inputs, but also through an Android smartphone application. The prototype will consist of a: Raspberry Pi, Bluetooth dongle, Wi-Fi dongle, user interface panel, motion sensor, and android application.

For actual monetization, using these parts would not be economically viable, because these parts are designed to be used by hobbyists, so they have more features than the final product needs, and are expensive. A final product will have to use much more specialized equipment. This is only a prototype for a senior project, so these expensive hobbyist parts are acceptable. The maximum bulk production cost for a single unit should be around \$45.00.

The smart light switch system will record when users change the status of the lights, and use that information to predictively change the lights for the user. The motion sensor will detect if the designated lighting area is idle for a period of time, and the system can save energy by turning off lights that are not in use. A flashing light alarm will be implemented as a substitute for existing sound alarms. Features such as Bluetooth control, Wi-Fi control, and the motion sensor, can be disabled by users.

The algorithm for pattern recognition will be based on results of a MS Thesis/project that are published in the report entitled *Predicting user behavior using transition probability* [1].

Abstract

Home automation is becoming more and more popular these days. Smart lighting is a crucial part of home automation. Most smart lighting systems for homes are expensive and complex. A smart light switch to replace ordinary light switches has been conceptually designed. An easy to install, smart lighting system is the goal of this project. The system will keep track of the patterns in which lights are used, and use those patterns for applications such as having lights ready for users before they get home. The system will be controlled by a Raspberry Pi, and will communicate with a smartphone application via Bluetooth, or over the internet through Wi-Fi. The final prototype designed in this project, will fit into a standard light switch box, be safe to install, and be controllable on a user interface panel, or from a smartphone application.

Table of Contents

Introduction	1
Problem Background	1
Problem Statement	1
Requirements and Specifications	1
Scope	3
Statement of Work	4
System Description	4
Design Approach	7
Method of Solution	7
Economic Analysis	8
Project Timeline	8
Division of Labor	9
Societal Impacts	9
Conclusion	10
Key Points	10
Specifications	10
Advantages	10
Summary	10
Appendix	11

I. INTRODUCTION

A. Problem Background

Home automation has been a trend since the 1980's; with the introduction of networking, home automation has become much more practical. Smart lighting is a key component for upcoming traits in society. There exist many versions of smart lighting that come in various forms (e.g bulbs, hubs, switches) that are commonly controlled from smartphones.

B. Problem Statement

For this project, the team must create an easy to install smart system for controlling home lighting. With conventional lights, it is not possible to control home lights from a distance, or know the status of home lights from out of the house. It is a challenge to control high voltage lights from a sensitive controller board. Lighting systems that learn the patterns in which home lights are used do not exist. A significant amount of energy is wasted when lights are left on in unoccupied rooms.

C. Requirements and Specifications

TABLE I. FUNCTIONAL REQUIREMENTS AND CONSTRAINTS

Characteristics	F	C
Embedded Debian Linux platform		X
Motion sensor shutoff	X	
Controllable via Android application		X
Manual button and switch control		X
Recognize and utilize light usage patterns	X	
Controls home lights		X
System fits in 1 gang work wall electric box		X
Easy to use	X	
Configurable modes	X	
Communication, and sensors are optional		X
System is safe	X	

Functional Requirement (F), Constraint (C)

Table I shows the functional requirements and constraints of the system. These characteristics are very general. Below, is a much more detailed explanation of the individual functional requirements and constraints.

Embedded Debian Linux platform

The system must be controlled by an embedded Debian Linux platform. The Debian Linux platform must be programmed and wired to control all other subsystems of this project. The Debian Linux platform will provide framework for communication with other subsystems.

Motion sensor shutoff

The system will use a motion sensor that can see motion in the room of the system's installation. If the motion sensor detects no movement in a room for a period of time -that is indicated by the user-, the lights in the room will be turned off by the system.

Controllable via Android application

The system must be able to be controlled by an Android application. The Android application will be developed by the team, and is only for communicating with the system. The Android application must also have access to a record of all lighting and system control events.

Manual button and switch control

At all times, the system must be able to be user controlled via manual buttons and switches. The buttons and switches must always be visible to users. Control from the manual buttons and switches must override any other control requests provided to the system.

Recognize and utilize light usage patterns

The system should recognize and utilize light usage patterns. Any event of button, switch, or other control requests will be recorded with a timestamp. The status of the system and room lights will be recorded in 15 minute intervals. The system will time and day of the week information in the pattern recognition. If desired by a user, the system will make suggested changes to the room lights based on the recognized light usage pattern.

Controls home lights

Upon installation, the system is replacing an existing light switch. The lights controlled by this switch must be able to be controlled by the system.

System fits in work wall electric box

A one-gang work wall electric box is a standard home installment for placing light switches to control home lights. The system must fit in a 1 gang work wall electric box, because this is the most common type of housing for home light switches.

Easy to use

The system should be intuitive. It is important that users are not frustrated when interfacing with the system.

Configurable modes

The system should have configurable modes. The functionality of the system should not always be the same. Users should be able to configure the system according to their preferences. The

various modes will be explained at greater depth in the “System State Diagram” portion of this proposal.

Communication and sensors are optional

The user must be able to disable or enable: the Android application communication, and the motion sensor. These features may prove to be undesirable by some users, and therefore must be optional.

System is safe

After installation, the electrical components of the system should be not visible or touchable by users. It is important that no users are harmed when interacting with the system.

D. Scope

In this project, the pattern recognition algorithm, and pattern recognition and utilization algorithm will be implemented. This senior project involves only the assembly of a prototype for the system. This project will result in a system that will control the lighting in an office.

The Smart Lighting System will not be fully constructed into a single unit that fits into a 1 gang new work wall electric box. The circuitry does not have to be entirely soldered together. For this project, it is simply important to prove that the system can fit into a 1 gang new work wall electric box, by any means necessary.

Making the system secure is not within the scope of this project. Safe installation of the system is will not be a result of this project.

II. STATEMENT OF WORK

A. System Description

The system will be a smart light switch that can replace ordinary light switches to control typical lights. The electronics will be protected from outside damage. Users control the system via four buttons and a switch on the panel of the system or through their smartphones over Bluetooth or internet. An application for android phones will be developed for the interface.

1) System Block Diagram (Black Box)

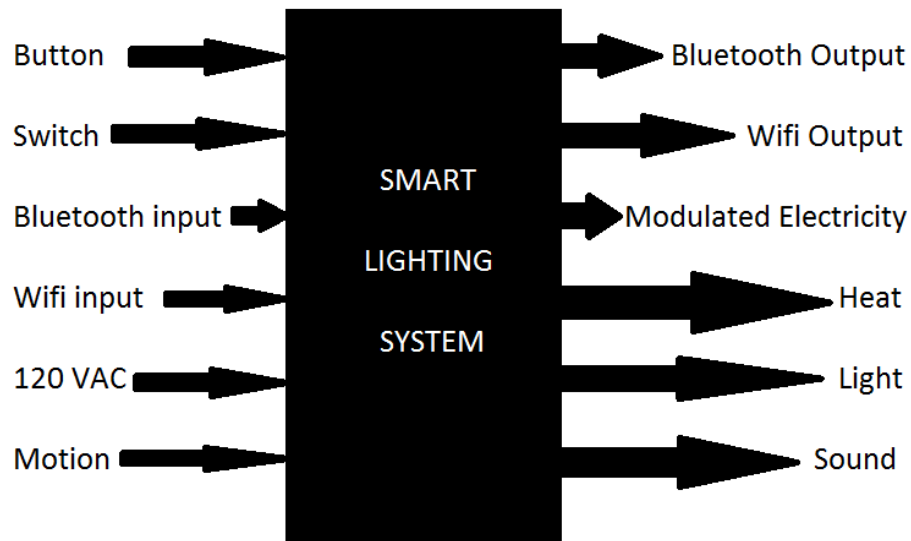


Fig. 1: Black box diagram: inputs and outputs of the system

Figure 1 shows the system black box. The system's inputs are shown on the left; outputs are shown on the right.

Inputs

Buttons and switches with some added circuitry are manual inputs to GPIO pins of the Debian Linux embedded system. The Bluetooth input comes from a smartphone application for wireless control. The Wi-Fi input is for internet control from the smartphone application. Motion is detected using a motion sensor. 120 VAC will be modulated to control the lights.

Outputs

Bluetooth is for sending information about the light usage history to a user's smartphone; Wi-Fi output sends the same information, except over the internet. Modulated electricity turns home lights on or off. Heat is generated from the system parts dissipating power. Indicator light emitting diodes (LED) output light to display the system's state. Sound comes from the clicking inside a relay switch.

2) Subsystem Block Diagram (Glass Box)

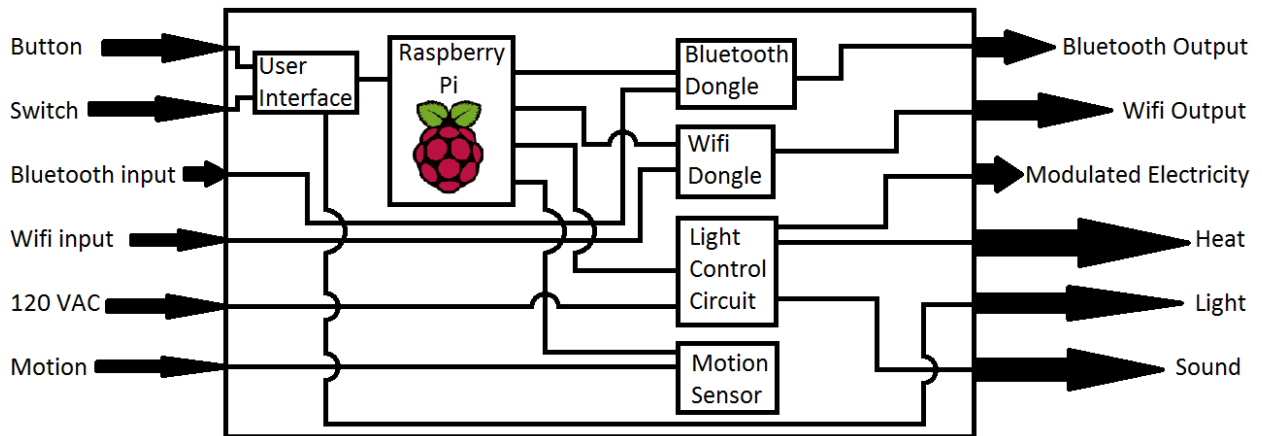


Fig. 2: Glass box diagram: key hardware components of the system

Figure 2 shows the system glass box. The Raspberry Pi handles all of the main communication and control of the system. The user interface is a panel with buttons and switches on the cover of the light switch box in which the system is installed. The Bluetooth and Wi-Fi dongles are connected to the Raspberry Pi USB ports for communication with a smartphone. The motion sensor will be placed on the front facing panel, so that it can observe its surroundings. The light control circuit will handle the high voltage light control.

A light control circuit is needed to manage the high voltage of typical lights, without breaking the sensitive Raspberry Pi board. It is important to isolate the voltage home lights from the reset of the system to avoid failure.

The user interface is a panel in which a user will control the system. The user interface panel will consist of various buttons and switches that are for control, and toggling functionalities.

3) System State Diagram

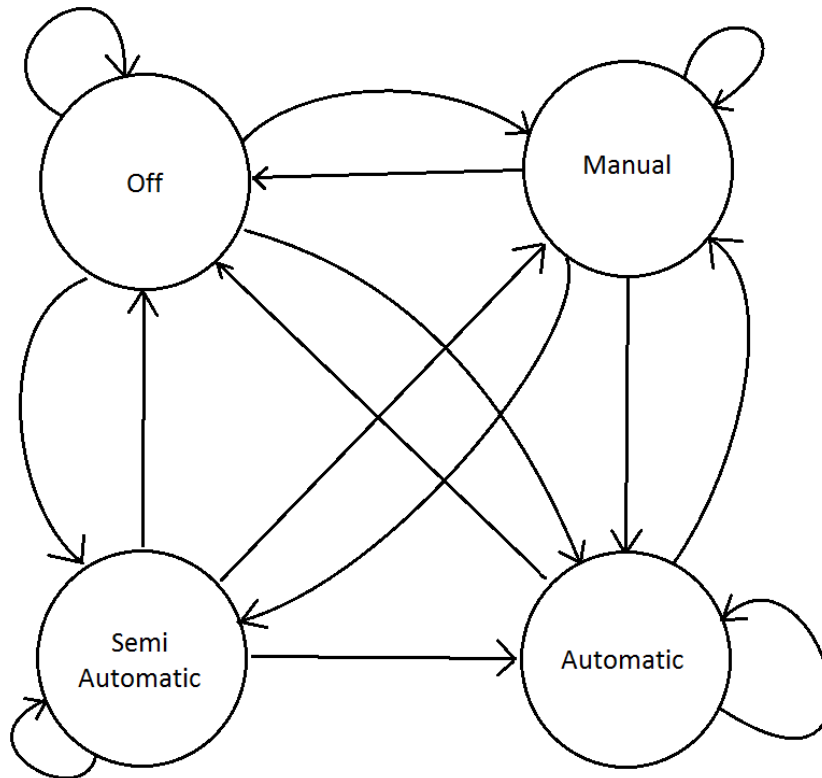


Fig. 3: State Diagram: the 4 main modes of the system

Figure 3 shows the four states of the system. In the off state, lights are always off. In the Manual state, the lights only change as requested. In the semi-automatic state, the system makes recommended changes to the light based off of the recognized pattern, and information from the motion sensor. In the automatic state, the system controls lights to mimic those lights usual usage. A user can change between the four states at any time through the Android application, or via four buttons shown on the panel. The buttons on the panel will have indicator LEDs to let the user know what state the system is in.

Off

In this state the lights are off, and any request to turn the lights on will be denied. The user may change to any other mode from the manual buttons, Bluetooth, or Wi-Fi (granted Bluetooth or Wi-Fi control are enabled). The system will record when a user attempts to change the light status, or if the mode is changed.

Manual

The system will make no changes to the light status, unless signaled to do so by the user in real time. Control may be through manual control, or smartphone (if enabled). The system will record when any changes are made to the lights, or if the mode is changed.

Semi-Automatic

The system will toggle the light status based on patterns recognized, user preset times, or the motion sensor observations (if enabled). If no motion is detected for 30 minutes, the lights will be turned off. The user may change the status of the lights from their smartphone or with the manual controls. The system will record when any changes are made to the lights, or if the mode is changed.

Automatic

All light status toggle requests are denied. The system will use recognized patterns to automatically turn lights on or off at typical times, so that it seems as if someone is home. The mode changing rules as explained in the aforementioned modes, still applies. The system will record when the mode is changed.

B. Design Approach

To make an easy to install smart light system, the team has decided to make a smart light switch that replaces ordinary light switches. This system will not require any specially designed light bulbs. The faceplate (panel) of the light switch box will have four buttons, four indicator LEDs, and a switch. Users may change the status of the lights, or mode of the system through the 4 buttons on the switch panel, or the switch on the panel.

A variety of skills are required for the completion of this senior project. Circuit designing is important for the light control subsystem and the user interface. The system will be programmed in Python, C++, and Bash. A smartphone application for Android will be developed. Communication over Wi-Fi internet and Bluetooth must be implemented.

The team does not yet have all necessary knowledge to complete this project, so some extra research is required. Methods of organizing and storing the recorded data must be researched. No team members have any experience in Android application programming. Managing the Wi-Fi settings on the Raspberry Pi from the smartphone is necessary, and must be researched. How to control multiple system units at once is another topic that must be researched.

C. Method of Solution

An algorithm for pattern recognition and prediction is to be developed for this project. The system will record every event change in the lighting system, whether it be from user inputs, or automatic decisions. The system will also record the status of the lights every 15 minutes. The system will use this information to work with a user to provide the best light usage experience. The algorithm will be based off of the Master Thesis *Predicting user behavior using transition probability* [1]. This solution can be tested by speeding up time in our system, feeding it generated artificial data, speeding the time from 15 minute intervals, to 5 second intervals, and watching to see if the system responds as intended.

The light control circuit will enable control of high voltage lights from the Raspberry Pi. The light control circuit consists of a high voltage relay switch, a transistor, a flyback protection diode, and a resistor. A pin output of the Raspberry Pi will turn the transistor on or off, which drives the relay switch. The resistor makes sure that a safe amount of current is drawn from the Raspberry Pi, and that an appropriate current is driving the relay switch. The flyback diode prevents high voltage spikes from the relay switch from damaging any other components of the system. The solution will be tested with a DC power supply from the lab that will act as 3V from the Raspberry Pi, and the 5V source. A simple desk lamp will act as the home lights. If all voltages are within a 10% range of theoretical design calculations, the solution works properly.

The user interface circuit has four switches for toggling the lighting status, Bluetooth control, Wi-Fi control, and motion sensor related decisions. At any time, a user can turn off Bluetooth control, Wi-Fi control, and motion sensor control. There are four buttons for choosing the system's state. There are 4 indicator LEDs for displaying what state the system is in. An LED will indicate if Bluetooth control is available, and another will indicate if Bluetooth is in communication with a smartphone. There will be two more LED's to indicate if motion sensor control, or Wi-Fi control are enabled. The motion sensor will be on the face of the user interface panel, so that it can see into the room of installation. The user interface panel will be tested by making a test program that will toggle LEDs based on the status of all button and switch inputs. An LED will also be toggled based on the output from the motion sensor. If all LEDs are toggled when their respective components are on or off, and all voltages are within a 10% range of theoretical design calculations, the solution is working properly.

The system should be safe for users. In order to keep the system safe, the user interface panel will be structured like a typical light switch cover. When screwed on, the panel will cover all wires and circuit components, except for the buttons, switches and the motion sensor. To test this solution, holes will be drilled into an existing light switch box cover to allow some circuit components to be interacted with. This solution is working properly, if all components can withstand one newton of force from a human finger, and all internal components of the system are still isolated.

D. Economic Analysis

This senior project is feasible. As Electrical Engineering students at Bradley University, many laboratory resources are available for the team. There exist plenty of online resources with information on Bluetooth programming with a Raspberry Pi and Android application.

Currently, \$97.33 of parts have been ordered for this project. The cost of mass production is estimated to be \$45.00 per unit. The system can be sold for \$60.00 to make adequate profits. Installation costs will be nothing, because this is a task that any homeowner can do. As for maintenance, if the system breaks, consumers will have to buy a new one if they so desire.

E. Project Timeline

Bluetooth communication and creating the hardware circuit are critical for the project, as many other parts depend on them. Internet communication over Wi-Fi must be set up in the android app

over Bluetooth. Testing the programs made requires a system that at the very least can be communicated with through buttons and switches.

The Gantt chart can be found in the appendix as table I. This shows all of the important deadlines and milestone tasks. The chart shows the order in which tasks will be completed by each group member, and in order. The top and bottom half will be completed by Dustin McCart and Alex Berian respectively.

F. Division of Labor

There are two group members for this project who will be working on different major parts of the project.

TABLE I. DIVISION OF LABOR FOR THE TWO TEAM MEMBERS

Alex Berian	Dustin McCart
All hardware	Initial basic programming
Bluetooth communication	Mode programming
Wi-Fi and internet communication	Data storage
Smartphone application	

Alex Berian will be focusing on all of the hardware. This includes the light control circuit, and the user interface as shown in fig 2. All non-manual communications will be designed for only the Android smartphone application. All front end and wireless programming will be completed by Alex Berian.

Dustin McCart will focus solely on the back end software. This includes reading/writing to pins on the Raspberry Pi, programming the various modes with or without pattern recognition and storing the saved data.

G. Societal Impact

Safety and liability is a huge concern for the smart lighting system project. When consumers install the system, to a light switch box, there is a chance they may shock themselves; a disclaimer or warning is necessary. When dealing with any home appliance that uses high voltage, it is beneficial to have the product certified by Underwriters Laboratories (UL). UL is the standard company that deems devices to be safe for consumer use. The system must be able to withstand an unpredictable user, in order to be safe for consumers.

The system is very beneficial for consumers who are looking for home automation. It is common that people are unable to wake up to loud music. Flashing lights may prove to be a more effective morning alarm system for certain individuals. The system will turn the lights off when nobody is using them, and someone forgets to shut them off, which saves a lot electricity. With the automatic mode on the system, consumers can create the illusion that they are home, when in fact they are on vacation. This helps prevent burglary.

III. CONCLUSION

A. Key Points

This project is a smart light switch with smartphone control over Bluetooth and internet. The system recognizes light usage patterns, and can make predictive changes to the lights based off of these patterns.

B. Specifications

The system's main controller and computer is a Linux embedded system. There is a motion sensor, Bluetooth USB dongle, and Wi-Fi USB dongle for smarter control. Wi-Fi, and Bluetooth control may be disabled with switches. The motion sensor may also be disabled with a switch. The system records every change made by users. Modes are always interchangeable. The system must fit into a 22-cu 1-gang new work wall electrical box. Based off of *Predicting user behavior using transition probability*, the system will recognize light usage patterns, and use those patterns to work with the user.

C. Advantages

The smart light system can improve people's day to day lives through alarms, or preset on/off times. The system can save energy by turning off lights that are not in use. Burglary can also be prevented with the automatic lighting mode.

D. Summary

There are many components to this project, and it is important to stay organized and know what it is each member must do, and when they must do it. Clearly defining the project is very important, especially for large teams, because it reduces the time in which team members are not doing anything productive.

IV. REFERENCES

[1]R. Heukels, *Predicting user behavior using transition probability*, 1st ed. Drienerlolaan: University of Twente, 2015.

V. APPENDIX

TABLE I. GANTT CHART: VISUAL SCHEDULE OF PROJECT TASKS

ID	Task Name	Start	Finish	DURATION	September-15					October-15			December-15			January-16			February-16			March-16
					15 th	17 th	22 th	24 th	---	20 th	22 th	---	10 th	15 th	17 th	19 th	21 th	---	4 th	9 th	11 th	---
1	Hardware circuit	9/15/2015	9/22/2015	3 session																		
2	Mode Programming	9/24/2015	12/17/2015	25 session																		
3	Mode programming Continued	1/21/2016	2/4/2016	5 session																		
4	Basic software	9/15/2015	9/22/2015	3 session																		
5	Bluetooth communication	9/24/2015	10/20/2015	8 session																		
6	Android app	10/22/2015	12/10/2015	15 session																		
7	Wifi communication	12/15/2015	12/17/2015	3 session																		
8	Wifi communication contiued	1/21/2016	2/9/2016	6 session																		
9	Final testing	2/11/2016	3/15/2016	10 session																		

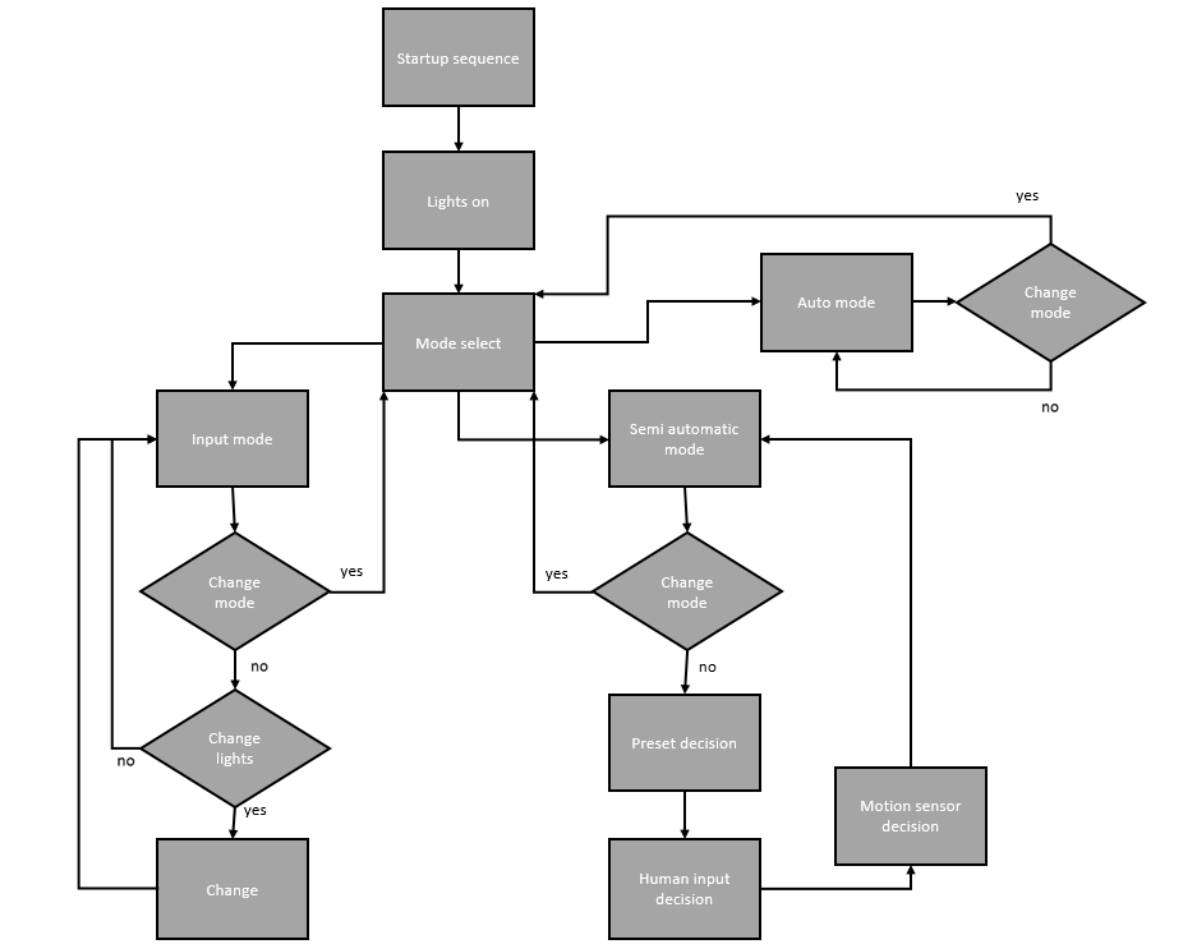


Fig. 4: Flow Chart: of the main loop

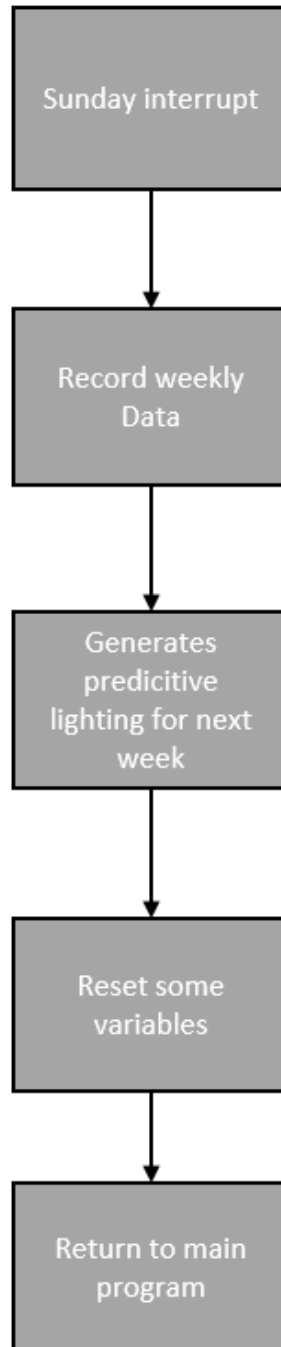


Fig. 6: Flow Chart: of the once per week tasks

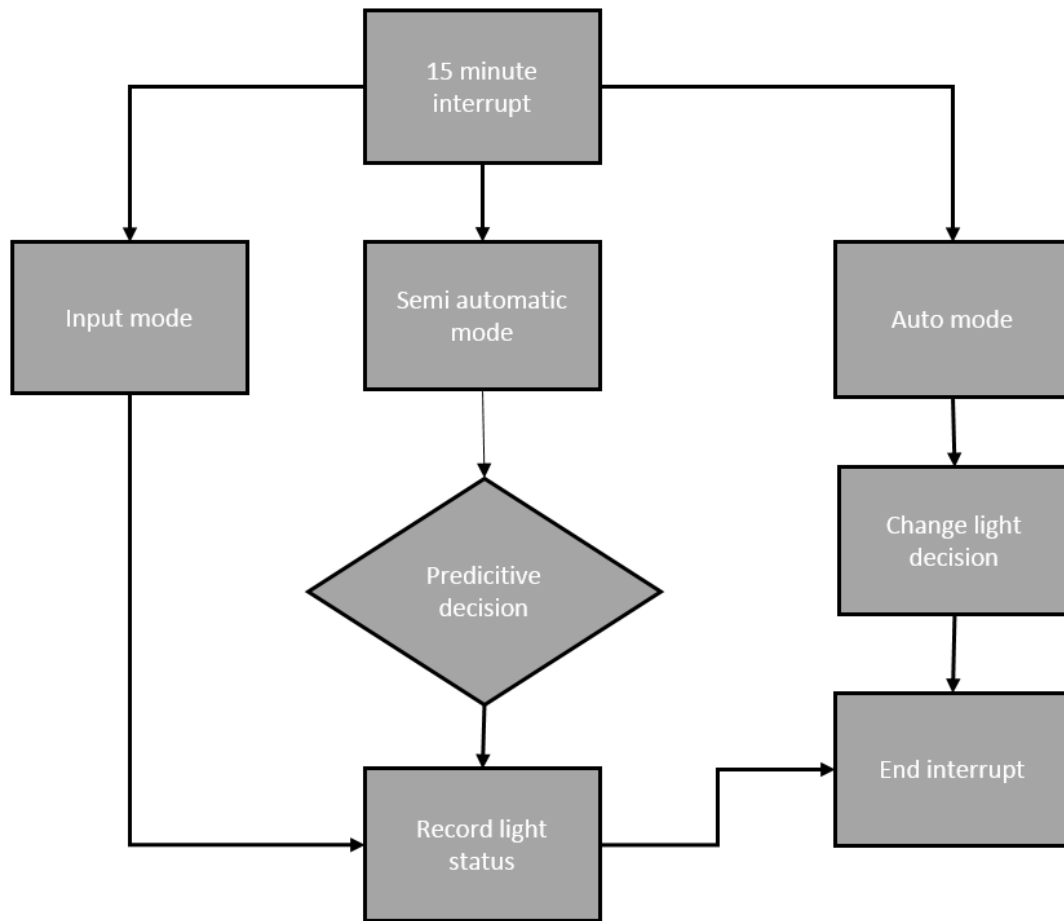


Fig. 7: Flow Chart: of the interrupt to occur every 15 minutes