Smart Home: Enhanced Home Automation based on Internet of Things (IoT)

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Abstract

The word “Smart” has become a regularly used term in the Information Technology in present. Staring with smart phones, it is now has extended to a number of areas such as smart automobiles, smart health care, smart schools, smart pens as well as smart homes. Smart home is the concept of an automated house where almost everything, especially electronic appliances can be controlled using a set of connected devices. Most of nowadays smart homes are fixated on static rule-based environment where the user behaviors are no significant relevance to the said smart home automation system.

In this study, a home automation system is proposed which is not only functioning on a set of rules but also in which the user actions are also considered. With the combination of smart devices and machine learning, a smart home approach is suggested where the user actions are recorded and analyzed to predict future events which related to the preferences of the user. The smart home is to learn and adopt to user’s behavior.

ACKNOWLEDGEMENTS

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Table of Contents

Table of Figures

Acronyms

IoT	Internet of Things
IT	Information Technology
ML	Machine Learning

Chapter 1: Introduction

With ***Ubiquitous computing***, the lives of the people have been made easier with computing being enabled by using any device, in any location, and in any format. A user interacts with the computer, which can exist in many different forms, including laptop computers, tablets and terminals in everyday objects such as a fridge or a pair of glasses [1]. These new devices which enables computing from anywhere are more commonly called as ***Things*** where related computing with ***Things*** are called as ***Internet of Things*** or ***IoT.*** A smart home can be identified as a strong application of IoT which controls the electronic appliances of the home over the Internet as per the user commands and/or prefers.

IoT is and can be used in many applications in a variety of industries as identified below and the possibilities are limitless.

- **Automotive**: a car (any vehicle) can be implemented to drive itself [2], do safe and self-parking and can be used to gather and analyze road information, traffic information, alerting when met with an accident, notify filling stations when running out of fuel etc.

- **Healthcare**: building partnerships with the wearable devices, clinical health ware can be used to monitor/gather and analyze one's body to identify possible heart failures [3], high/low pressure situations, sudden body malfunctioning, infant monitoring and many more. Intelligent applications can be built in order to act as a human doctor to diagnose illness when symptoms are provided.

- **Smart transportation**: can be used to provide safe and sound transportation to its passengers. Avoid possible road accidents by sensing the passengers/vehicles nearby, route identification based on low traffic roads once the source and the destination is provided [4], suggesting places to eat, drink and relax when on a tour are some of the interesting applications of smart transportation.

- **Retail**: use IoT to increase supply chain efficiencies, suggest the grocery list when one is shopping for items in a supermarket or a retailer shop by identifying the frequently needed items are some of the IoT enabled features in this industry [5].

- **Smart home**: identify one's voice at the door step itself and automated home appliances are ready to welcome the owner home by setting the preferred home environment. Automated light system enlightens the home and the surrounding where the smart parking will guide the vehicle to be parked nicely into the garage. Entering the home, user is identified by the security system while the smart refrigerator will suggest the dinner plan as per the available items with in it [6].

Though IoT has been a catchword in the IT industry nowadays and noted as the "***The future is Internet of Things",*** the concept of IoT was introduced in early 1990s'. A paper was published by the well-known scientist Mark Weiser on the topic of Ubiquitous computing which led him to be considered as the father of the said subject. He stated that "*Already computers in light switches, thermostats, stereos and ovens help to activate the world. These machines and more will be interconnected in a ubiquitous network*"

In this document, main concern lies with the IoT enabled Home Automation. This chapter is dedicated for that topic.

IoT has made it possible to activate/turn on home appliances through smart devices which are connected to more devices or networks via different wireless protocols such as Bluetooth, NFC, Wi-Fi, 3G, etc. without approaching the home physically. For example, it's possible to turn on the lights of the house when it's getting dark by a single click of a modern-day smartphone with the precise application. This practice is called as "***Home Automation***" and it uses appropriate sensors and microprocessors gather and process information as required.

Although home automation has been able to make the day-today life of the man easier, simpler and more comfortable most of the time it is been developed as a static application with fixed and definitive rule set(s) to act upon when the specified conditionals are met in the form of **IF** <condition> **THEN** <action>. Hence leading to possible errors or failures. Also, this static behavior of such applications limits the adaptability to changing requirements. For example, IF <it is dark> THEN <turn on the lights>, may not verify the cause of the darkness as in is it getting dark due to the time of day or is it dark because someone is purposely doing so. If it is the second cause, it might be a security threat to the house. It is important to identify such security threat when working in a fully automated environment.

1.1 The Problem

This document is proposing an enhancement to an existing Home Automation system. A static home automation system has been developed by a group of 2nd year undergraduate students in 2016 under the supervision of Senior Lecturer Mr. Gihan Senevirathne. This is developed as a Proof of Concept (POC). The project is named as "***Happy Home".*** This can be integrated into a house's electrical system and allows one to wirelessly control several electronic appliances within the house. The system can be controlled from a web portal and an android application connected to the same local intranet or the Internet. The Home appliance control system receives commands from either remote device that is manipulated by the user or from sensors which are responsible to detect environmental deployed and wired in the household. The system is using a variety of sensors to sense and gather data from the surrounding environment and Raspberry pi 3 model B with Arduino boards to control the system as microservices.

Main features of this application include turning on/off electronic appliances as user commands, gather and send sensor data to the main controller, keep track of the sensor information and state to identify a possible problematic situation and notify the user.

A high-level system architecture diagram is as follows.

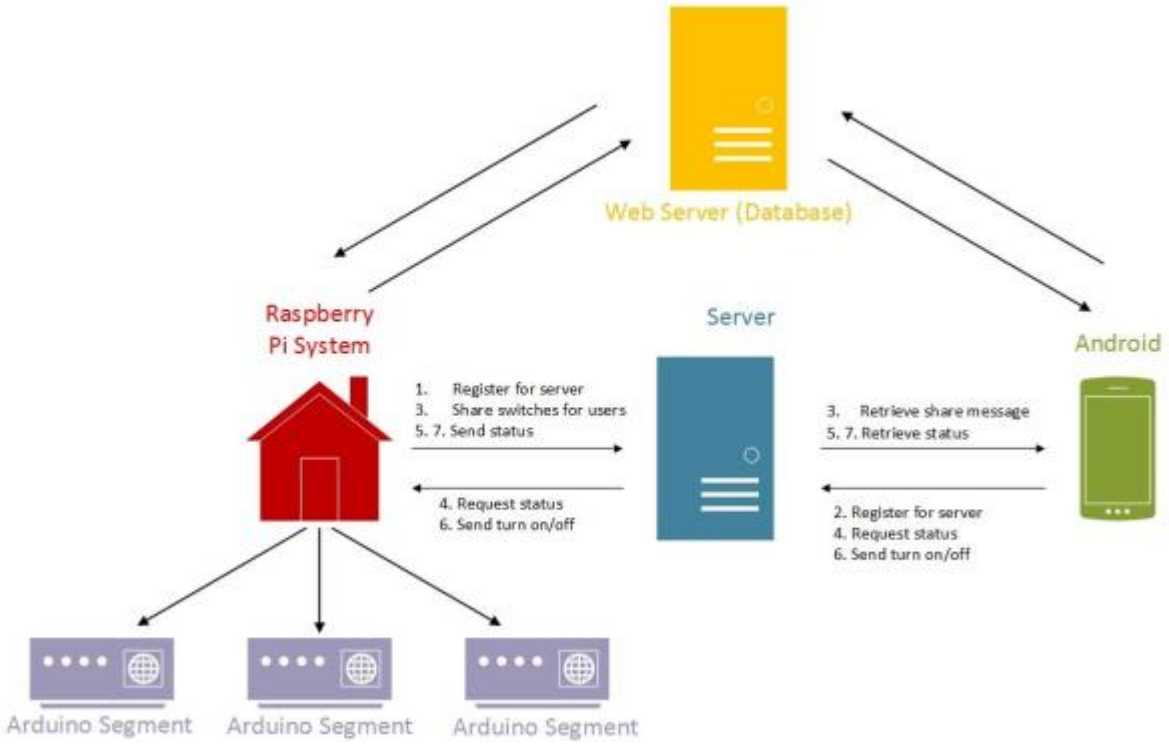

Figure 1- High level architecture of Happy Home

Following features are available in the existing home automation system.

- Turn on/off bulbs according to user preference.
- Check the humidity and temperature in any time user wants.
- Automatically turn on/off fan according to humidity level.
- Check the water level in a tank any time user wants
- Send a warning message to user when water level of the tank is low
- Send a warning message to user when a water leakage found
- Alarm and Send a message to the user when a gas leakage found
- Send a warning message to user when rainfall detected
- Send a message to user when a movement detected from motion sensor.
- Change settings according to user's preference

In the existing application, the devices controlling rules has been defined as fixed and static hence no rule can be overridden by the user. In addition to that the current functionality does not show whether the electronic appliances are operated as commanded remotely. The problem that is being addressed by this proposal is how to transfer an existing home automation system to a smart/intelligent system in order to make smart/intelligent decisions not only based on the rules but also based on the data gathered by observing and learning the user behavior in the environment that it has been exposed to by adapting to the user preferences.

1.2 Motivation

Internet of Things is the network of devices that are connected to the Intern et, devices are connected to the Internet to monitor gather and analyze data through these devices and incorporated sensors. Below graph shows Internet of Things (IoT) connected devices installed base worldwide from 2015 to 2025 (in billions) [7].

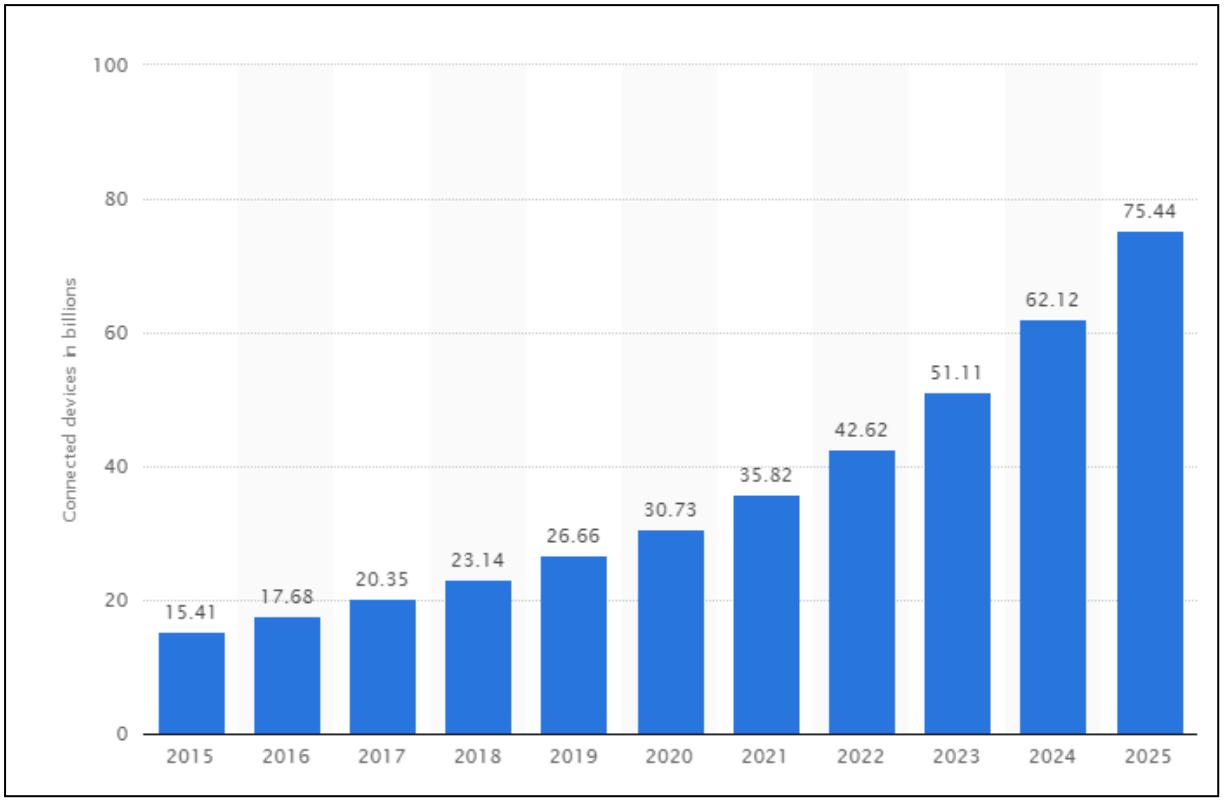

Figure 2- Connected devices from 2015 to 2020

In a nutshell, IoT is the capability of sensing, communication, interacting and collaborating with connected devices and create a network of physical devices. It is important to highlight the fact that IoT is not only turning on/off appliances, but the collected data is the matter. IoT can be greatly beneficial in a connected home (smart home) to identify theft alerts, for automated irrigation systems, in a connected hospital (smart hospital) to run analytics on various machines using the collected data from the patients in order to optimize future requirements and in many areas as discussed in above chapter. The most advantage of these collected data is that these can be used to get insights of the application and use in order to enhance the usage furthermore.

1.4 Research contribution

The proposed solution is an enhanced Home Automation system which is planned to use several sensors to detect environment states (temperature, humidity, lighting) and a seamless structured control structure to provide a better flexible control and, machine learning techniques to improve the set of control rules that is used to control the home electronic appliances. This adapts user behavior to individual users by learning their tastes during the interaction with the automation, in order to construct a profile that can be later exploited to select relevant actions [8]. To gather user characteristics, implicit process (e.g., observing the user behavior), will be used and a user model to be exploited to enable additivity mechanisms during the interaction with the proposed system. Ultimately the users will have a safe, enjoyable, economical, energy efficient, convenient and user-friendly home.

The solution should help the users to reduce their energy costs without compromising their comfort. It also needs to reduce the stress of the users by handling certain day-to-day activities automatically.

Following objectives can be identified in order to reach the goals mentioned above:

- Identifying important/ common automation requirements (concerns and aspects) of a typical home.
- Identifying home activities that can be automated and their priorities.
- Identifying already known techniques or rules that can be used to automate each identified home activities.
- Develop an extendable home automation structure.
- Implement a Proof of Concept (POC) and evaluate its acceptability.
- Make the solution adaptable by adopting machine learning techniques for rule evolution.
- Monitor and visualize power consumption of the household so utilize the power in a cost and energy efficient way.

In the existing application, as discussed in the above chapter the devices controlling rules has been defined as fixed and static hence no rule can be overridden by the user once the application is deployed and installed. In addition to that the current functionality does not show whether the electronic appliances are operated as commanded remotely. Proposed

solution is an enhancement of this existing system by eliminating the usage of static rules by using an intelligent system of machine learning and user profiling.

Following benefits are possible from the proposed solution;

- Increased independence and greater control of their home environment.
- Time effectiveness.
- Improve their personal safety
- Increase their home's energy efficiency.
- Allows them to monitor and control their homes while they are away.

1.5 Scope of Project

This project is carried out as a deliverable for the completion of Master's program (computer science) of University of Colombo, School of Computing. Project scope can be defined as follows:

- time allocated is one year (two semesters)
- Technologies to be used are IoT (Internet of Things), sensor devices controlled by NodeMcu/ Arduino/ Raspberry Pi and machine learning algorithms (python)

Chapter 2: Background

The main objective of a home automation system is to provide efficient, convenient, and safe ways for home inhabitants to access their homes irrespective of the time and place. With the drastic changes that the Information Technology field faced throughout the recent years, the idea and the implementation of the home automation systems has been also considerably changed in many aspects.

Stewart Brand identifies a building with the aid of 6 S's as below figure [9]. As a home is also a building it can inherit the same structure. In the context of home automation, the focus lies on the inner most layer i.e. **STUFF**. Furniture, home appliances and personal items which can be considered as movable and replaceable items with in the house hold belongs to this category. The modern-day smart homes are more focused on the electronic appliances such as cameras, temperature/humidity sensors, lights, refrigerators, washing machines, air conditioners, coffee machines etc. only as those few selected home appliances can receiving/send commands/data back and forth with the enhancement of IoT.

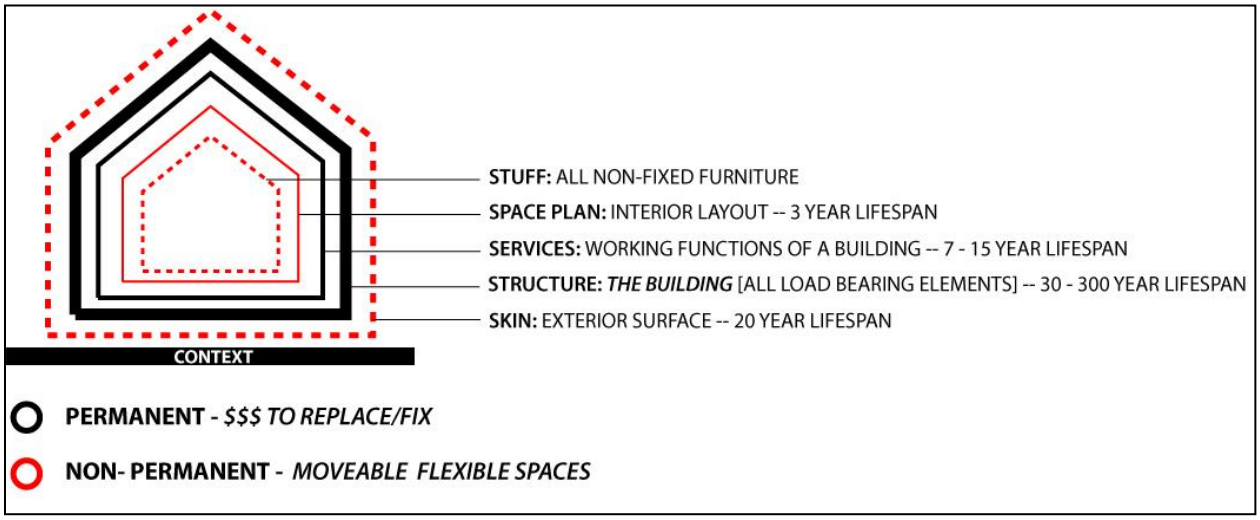

Figure 3 - 6 S's

Internet of Things (IoT) helps to achieve the ultimate need of the people at the present time, i.e. to be and stay connected irrespective of the time, place and method. With this powerful capability it has been easier to create a number of automated applications for continuous control and monitoring of different things within the household such as lights, fans, various sensors even vehicles as the user prefers. Most of these applications use a central controller such as Arduino or Raspberry Pi and can be accessed via a web based, SMS based, Bluetooth based or more frequently mobile based applications.

Usually a home automation system includes following core modules

- **User interface**: visualizes the current state of the home appliances. Used to emit commands to those appliances when needed.

  Ex: web site or mobile app to visualize home and its surrounding data
- **Transmission mode**: to send/receive data/commands from/to devices (or sensors) in a secure manner.

  Ex: Bluetooth signals, radio waves
- **Central controller**: connects the user interface and the devices (or sensors) and process the data with a limited processing power as these are intended to be used for minor applications.

  Ex: Arduino, Raspberry Pi
- **Electronic devices**: placed within the house which sends continuous data/signal to be monitored and controlled.

  Ex: lights, fans, washing machines

Capability of controlling devices through Internet connectivity, Scalability and security can be highlighted as the most important requirements among the home automation systems.

Following diagram displays categories of Home Automation systems that are being developed using the latest technologies [10].

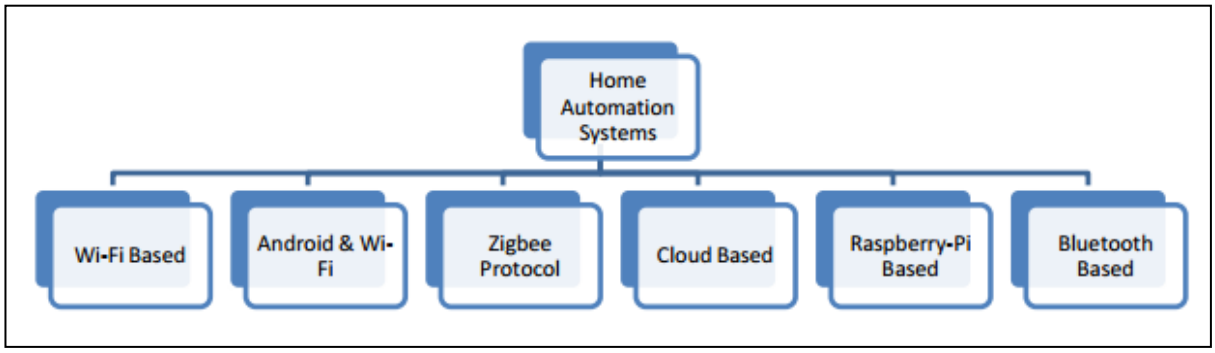

Figure 4 - Types of Home Automation Systems

Early home automation systems have faced many challenges and problems such as high manufacturing costs, high development costs, high installation costs, additional service and support costs, lack of home automation standards, consumer unfamiliarity with technology, and complex user interfaces.

2.1 Literature Review

Following section in this document describes several home automation systems and a few time series forecasting algorithms that have been developed and presented.

2.1.1 Home Automation Systems

Wi-Fi based home automation system is presented as a white paper which propose a low cost, secure, ubiquitously accessible, auto-configurable, remotely controlled solution. This is presented as an alternative for wired communicated system approach in order to address the flexibility of adopting the system for already built homes. The system consists of two main parts, web server (developed using asp.net) to provide user interface to the LAN or remote users to control the hardware within the home and hardware interface module with the sensors for the automation system. Wi-Fi has been chosen as the communication strategy to increase the system mobility and the scalability. The core of the hardware interface module is an Arduino microcontroller. The system is capable of monitoring and controlling lights of the house, door status and locking, window status and locking, connected electronic appliances [11].

A mobile based home automation was presented for a low cost smart home system, which is based on the Android app which communicates with the micro-webserver providing the switching functionalities. Android application was used to access the application. SMS alerts are sent when the home devices such as incandescent bulbs, various AC and DC appliances are on. Whenever web server detects an active or inactive internet connection, the server sends command to GSM modem about sending SMS to a prescribed number. User access a web server from Internet enabled device (PC or mobile) and control the home appliances through the web interface or mobile application (android based). This uses a RESTful web service and an Arduino microcontroller [12].

Another home automation system is presented with the feature of the ***flexible task scheduling***, An Integrated and Low-Cost Home Automation System with Flexible Task Scheduling which can be programmed and controlled remotely. This system is flexible enough to easily include new devices with other interfaces such as the popular X10. The central control system is developed using the robotic programming environment RIDE that allows defining, monitoring and debugging tasks modeled as Petri nets [13]. While running, the execution of tasks can be easily monitored watching the evolution of the different Petri nets. Besides monitoring, the system can be instrumented to log

state changes at different levels of detail. The devices of the house are being connected via Modbus using the building's local network (Ethernet) and are exchanging information with a central server (JCentral server which is implemented using publisher subscriber mechanism) using an Arduino microcontroller.

GSM Based Home Automation, Safety and Security System Using Android Mobile Phone presents a remote appliance control system which can control different household appliances by sending a SMS. The working of the project is divided into three parts which are home automation, home safety and security system [14]. For home automation android app will send a SMS to GSM model which will be forwarded to the microcontroller. The microcontroller then extracts the message and the device in subject will be then controlled accordingly. for home safety system smoke detector and LPG gas detector has been used which will detect gas or smoke and send a feedback to the microcontroller to ring an alarm if certain threshold values are reached. An ultrasonic sensor is used for the home security system for intruder detection.

Bluetooth Based Device Automation System Using Cellphone was presented to propose a low cost and scalable solution that allow variety of devices to be controlled with minimum changes to its core. A phone is used to emit commands to turn a device ON/OFF. Once the command has been sent to turn ON a device, the feedback circuit senses the current and gives an output signal by turning ON a respective led on the switching circuitry indicating that the device is ON [15]. Otherwise, the device is malfunctioning indicating that the command was not executed successfully. It is also possible to operate the appliances of Home or Office from long distance that is out of Bluetooth range area. This can be done with the help of Web Server. A website having all the device names included in it in order to allow outside access.

2.1.2. Time Series Forecasting

Time series forecasting is an important branch of machine learning. A normal machine learning dataset is a collection of observations where time does not play an important part of the overall process. But a time series dataset has a huge dependency with the time as the name implies itself. A time component, more sophisticatedly known as a time dimension is added as an explicit order dependence between the observations in the time series data set [16]. These time series data can be collected in many different domains such as education, economics, industrial, science and research etc. Essentially, to visualize these time series data, graphs are used as a standard where the observations are plotted against the corresponding time factor. In the long run, these visualizations help the researchers to identify certain patterns of event occurring and isolate anomalies of the events. Below is such a graph representing time series data on shampoo sales vs year.

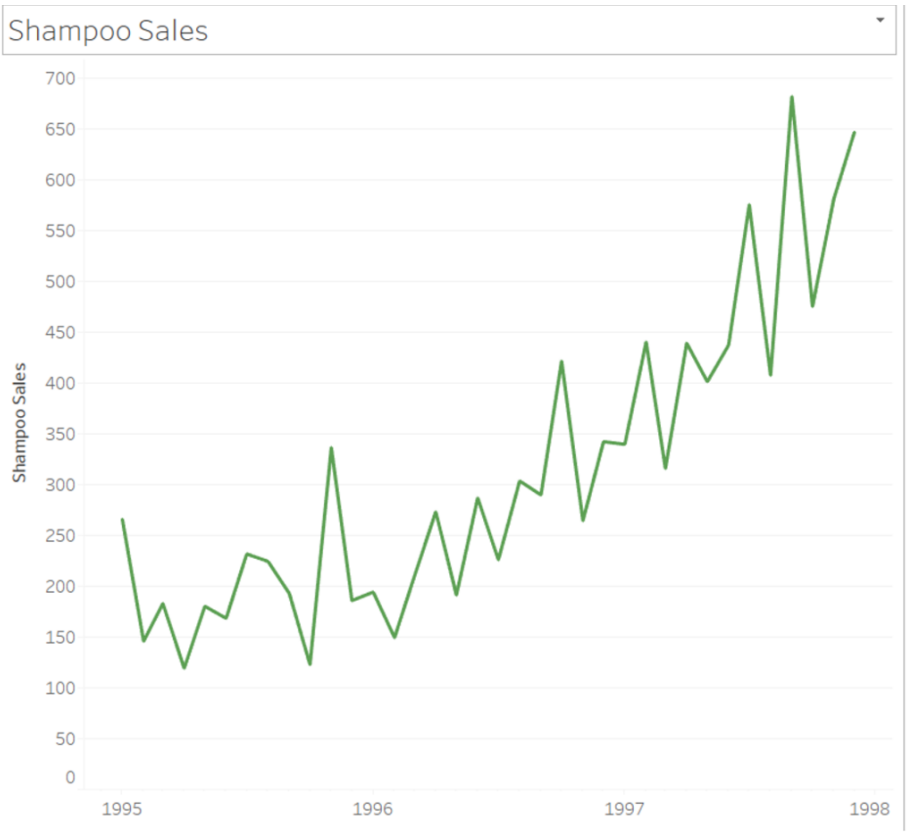

Figure 5 - A graph representing time series data on shampoo sales

Time series data has 4 main components [16].

1. ***Level***. The baseline value for the series if it were a straight line.
2. ***Noise***. The optional variability in the observations that cannot be explained by the model.
3. ***Trend****. The optional and often linear increasing or decreasing behavior of the series over time.
4. ***Seasonality****. The optional repeating patterns or cycles of behavior over time.

* optional components

Time series modeling is considered as a dynamic research area which focuses on careful studying of collected past observations of a time series to develop an appropriate model. This developed model is used to describe the innate structure of the series in observation and to make forecasts. Forecasting mainly focus on a selected model fit on historical data/observations and using them to predict future observations. There are a few time series forecasting models developed by many other researchers over the time and below are few which are identified as suitable for this project by following the literature.

Autoregressive (AR) **-** An autoregressive (AR) model predicts future behavior based on past behavior. It's used for forecasting when there is some correlation between values in a time series and the values that precede and succeed them. Past data is used to model the behavior. The process is basically a linear regression of the data in the current series against one or more past values in the same series. The notation **AR(p)** indicates an autoregressive model of order p. The AR(p) model is defined as

$$X_t = c + \sum_{i=1}^{p} \varphi_i X_{t-i} + \varepsilon_t$$

where $\Psi_1 \ldots \Psi_p$ are the parameters of the model, c is a constant, and ε_t is white noise [17].

Moving Average (MA) - A moving average (MA) is a widely used indicator in technical analysis that helps smooth out data set by filtering out the "noise" from random short-term data fluctuations. It is a trend-following, or lagging, indicator because it is based on past observations. This is a common approach for modeling univariate time series. The notation MA(q) refers to the moving average model of order q as below.

$$X_t = \mu + \varepsilon_t + \theta_1 \varepsilon_{t-1} + \cdots + \theta_q \varepsilon_{t-q}$$

where μ is the mean of the series, the θ_1, ..., θ_q are the parameters of the model. and the ε_t, ε_{t-1},…, ε_{t-q} are white noise error terms. The value of q is called the order of the MA model [18].

Autoregressive Moving Average (ARMA) Given a time series of data set X_t, the ARMA model is a tool for understanding and predicting future values in this series. The **AR** part involves regressing the variable on its own past values. The **MA** part involves modeling the error term as a linear combination of error terms occurring contemporaneously and at various times in the past. The model is usually referred to as the **ARMA(p,q) model** where p is the order of the AR part and q is the order of the MA part. ARMA(p,q) model is defined as below [19].

$$X_t = c + \varepsilon_t + \sum_{i=1}^{p} \varphi_i X_{t-i} + \sum_{i=1}^{q} \theta_i \varepsilon_{t-i}$$

Autoregressive Integrated Moving Average (ARIMA) - is a statistical analysis model that uses time series data to understand the data set better and/or to predict future trends based on the understood data. An autoregressive integrated moving average model is a form of regression analysis that gauges the strength of one dependent variable relative to other changing variables. This is also a generalization of an autoregressive moving average (ARMA) model. For ARIMA models, a standard notation would be ARIMA with p, d, and q, where integer values substitute for the parameters to indicate the type of ARIMA model used. The parameters can be defined as below [20].

- p: the number of lag observations in the model; also known as the lag order.
- d: the number of times that the raw observations are differenced; also known as the degree of differencing.
- q: the size of the moving average window; also known as the order of the moving average.

Chapter 3: Analysis and Design

In this section, the steps of the process that are followed by the project team throughout the research project will be described. The focus here is explaining the flow of the research project. It will describe how requirement gathering will be done, which process model to follow, design deployment techniques, hardware and software requirements and the resource and project management plan.

3.1 Methodology

The main aim of this research is to develop a self –enhancing home automation system based on IoT. As discussed in the above chapters' traditional home automation systems are not flexible most are built on static rules. With the use of Machine Language this document proposes a home automation system which will observe and adopt to the user behavior.

Instead of simply turning an electronic device on or off, it would be much helpful and interesting to remind the user to switch on a device on a certain time at which it is most cost effective. Also, how easy would it be if the Air conditioner itself decrease the temperature as the user prefers without user explicitly handling it. Proposed system addresses research questions of the similar context.

3.1.1 Gathering requirements

Different methods and techniques are used to obtain information which was vital for the proposed project. Many research papers were read, and Internet was browsed to find documents, articles that were published in relation to this type of project work. Potential details were obtained, technical requirements and identify the current situation of home automation systems as well as what areas should be improved and researched upon were identified.

3.1.2 Requirement analysis

After the requirement gathering phase, some of the major issues of the current home automation systems were identified. Some of these identified issues are listed below.

a) A variety of apps to be setup, learnt and used of different vendors
b) Difficulty of making different devices work as one system
c) Each device requires separate power units and wireless adapter for network connection
d) Combined cost is relatively high for a home automation system
e) Most are based on static rules to control the home automation system.

3.1.3 Design and implementation of the system

Home automation system is developed using a collection of sensors (listed in the below under the hardware requirements) to gather environmental data (temperature, humidity, air pressure etc). Raspberry PI 3 is used as the main central controller. The system is accessible via a web portal hosted in the Internet. User can login to the web portal and perform turning on/off electronic appliances. The system records the user actions in order to train the machine learning algorithm which is used to predict user action in similar context in the future.

Machine learning (ML) and User Modeling are high terms in this context. A user model consists mainly of knowledge about the individual preferences which determine the user's behavior . Machine learning (ML) techniques have been applied to user modeling problems for acquiring models of individual users interacting with an information system and grouping them into communities or stereotypes with common interests [21].

User models are mainly described using following attributes [22]

a) The cognitive processes that underlie the user's actions
b) The differences between the user's skills and expert skills
c) The user's behavioral patterns or preferences
d) The user's characteristics.

In the proposed home automation system is it expected to model the user based on (c) The user's behavioral patterns or preferences. The learning algorithm is developed under the category of supervised learning as the system is observing the user behavior for a certain time period to identify certain patterns before prediction. The algorithm is implemented using Python (version 3)

HTML5, CSS3 and PHP is used to develop the web console to access the home automation system via Internet and MySQL is used to store the respective data which records the day today activities and these data is used in the Machine Learning Algorithm in Python.

3.1.4 Enhanced Home Automation system overview

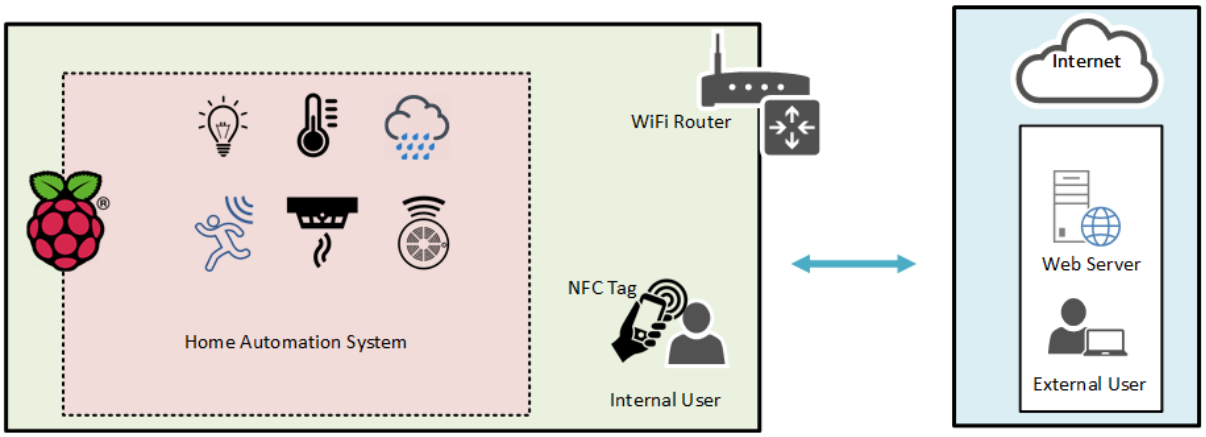

Figure 6 - Home automation system (SMART HOME) overview

User creates an account in the web portal and login to the web portal. He sets his preferences in the web portal how the connected devices (lights, alarms etc.) should be operated during certain time periods. User is given an NFC tag which can be read by NFC reader which resided in the home. When user taps the NFC tag to the reader it will read the NFC tag value and the raspberry pi will load the user preferences (set earlier) which is mapping the NFC tag values. if the user is not satisfied with the set-up environment, he/she may change certain devices (lightings, alarms etc.) which will be recorded as new preferences for that user. These changes will be used to train the machine learning algorithm to perform user modelling.

3.1.5 Predict future events

When predicting future values, or technically known as “forecasting” based on a collection of time series data of observations, it is mandatory to have an appropriate model for these time series data. This is vital as this model reflects the underlying structure of the time series data. A time series model is considered as either linear of non-linear as per the most frequent value of the time series is a linear or non-linear function of past observations. The models mentioned in above sections are all linear time series models ARMA model is used in the process of forecasting nest time of selected events occurring in the Smart Home project as the most appropriate model due to the simplicity of understanding and applying for different problem solving along with the easiness of implementation.

The time series data was collected by using a MYSQL database, which records data of certain events occurring, such as switching on kitchen light. The database records which electronic equipment is switched on or off, the timestamp of the event and the current operational value of the said electronic appliances such as the current set temperature of the AC if that value is applicable for the said appliance. Note that for appliances similar to lights are having null for these time of current operational values as lights are having only two states on and off.

These data are recorded throughout the day based on the user performing such actions with in the household. A machine learning algorithm written using Python is used to model the data for each specific event using ARMA model. This algorithm runs as a scheduled task daily at a given time period. When processing time series data it is important perform data cleaning, scaling, and even transformation as required as raw data may have noise and outliers which cause erroneous and unrealistic forecasting. Hence Python algorithm discards observations which are considered as outliers when modelling the data set to increase the accuracy of the forecast. Outliers are time series observations which extends beyond the normal range of the data. To remove such outliers, statistical modelling is used.

Once the outliers are removed and data is cleansed to be processed by the algorithm, it models that data using ARMA model and predicts the next event occurrence time. This new time is recorded in the database to be extracted later to perform the actual event operation. When the estimated time is arrived, the system notifies the used about the event operation performance via a mobile application and the user either accepts or discards the prediction. User’s acceptance of rejection of the predicted time of event occurrence, acts as an input for the next round of time series forecasting.

3.1.6 Software and hardware requirements

Software requirements

- Windows 10
- NodeJS
- Python
- Rasbian Linux
- Eclipse
- MYSQL database

Hardware

- DHT11 Digital Temperature & Humidity sensor Module
- PIR Motion sensor
- Rain sensor module/ rain water module
- HC-SR04 ultra sonic sensor
- Fire detection of flame sensor module
- MQ2 Gas Sensor Module for LPG Propane Hydrogen
- Raspberry pi 3 module B
- NFC module
- Relay – (1 channel module)
- SD card 32GB class 10
- Circuit wires
- Mq5 Natural Gas sensor
- RJ 45 Network cable
- HDMI cable
- Power Adapter 5V micro USB 2.5 A
- Interface card(s)
- HDMI 2 VGA cable
- Box (enclosure)
- Wi-Fi modules
- Wireless router

Chapter 4: Evaluation

4.1 Evaluation Approach

To evaluate the Smart home project, a scenario-based approach is standard. This method includes evaluation of a happy path (best case scenario) and possible loop holes (worst case scenario) in a proposed flow. Based on the analysis of these scenarios, a conclusion will be provided at the end of this document.

The project can be also evaluated by the result of the learning algorithm. A Machine learning algorithm is used to predict the time of a selected event in a house hold i.e. when will be kitchen light switched off at the end of the day. This estimation is done based on the collected data on similar event for a selected time range. The user of the system has the authority to accept or override the estimation time. Based on this user input the accuracy of the learning algorithm can be evaluated. This user input is of two types as below

- Accepting the predicted time offered by the system after pushing data to the Machine Learning Algorithm – in this scenario the event will occur at the suggested time and a data record will be added to the back-end data base as well.

- Decline the predicted time offered by the system – in this scenario the predicted value returned by the Machine Learning Algorithm is overridden by the user preference and this new value will be saved as a data record. These changes are fed to the Machine Learning Algorithm daily to estimate the next event occurring time.

The system is functioning in two modes

- Learning mode – where the previous event occurring times are fed to the Machine Learning Algorithm to fetch the future event occurring times of certain events. In this

- Override mode – where the user inputs will be considered solely to determine the time of the next event

The evaluation can be done by taking the number of times the user has overridden the estimation as a metric to calculate the accuracy of the results.

4.2 Evaluation Procedure

The primary objective of this project is to make a sophisticated Home Automation system which does not rely only on the environmental changes but also user preferences and user inputs. It is important to note that there exist various software solutions developed by various vendors to automate home appliances process by providing smart devices and other techniques. However, user centric preferences analysis or time series prediction based on user inputs was not their primary concern. Therefore, finding an appropriate mechanism to input user preferences (i.e time of switching on a certain light in a household, what is the user preferred room temperature so A/C can be controlled) and predicting these values based on previous data using Machine Learning algorithm is more focused in this document rather than focusing on process home Automation with electronic appliances. For the completeness and clarity of the project, initially a home automation system with a sample light device connected is presented.

Chapter 5: Results and Discussion

This chapter describes the results of applying ARMA model (implemented in Python3) on a simulated time series data set for a selected event i.e. turning kitchen light ON daily. This model is used to predict the time for the same event occurring next day based on the simulated data set. Only one event is selected for the discussion of this document for clarity and better understanding of the study. It is important to note that same approach can be used to predict future values for the other events related to the other electronic appliances of the smart home.

This chapter also summarizes the entire study and use observations to set new levels of future work.

5.1 Inputs and process data using ARMA model

The event data is persisted in a MySQL database table (named "itemstatus") as and when the event occurred with the relevant electronic appliances id, item status, recorded date and recoded timestamp. Unix timestamp is used when recording the time of the said event occurring. A sample data set is as below.

status_id	item_id	status_value	recorded_date ▲ 1	recorded_time
127	1	on	2019-04-01	1554093004
128	1	on	2019-04-02	1554179584
129	1	on	2019-04-03	1554265984
130	1	on	2019-04-04	1554352381
131	1	on	2019-04-05	1554438721
132	1	on	2019-04-06	1557117124
133	1	on	2019-04-07	1557203104
134	1	on	2019-04-08	1554697921
135	1	on	2019-04-09	1554784201
136	1	on	2019-04-10	1554870721
137	1	on	2019-04-11	1554957121
138	1	on	2019-04-12	1555043532
139	1	on	2019-04-13	1557721804
140	1	on	2019-04-14	1557808204
141	1	on	2019-04-15	1555302552
142	1	on	2019-04-16	1555389072
143	1	on	2019-04-17	1555475412
144	1	on	2019-04-18	1555561992
145	1	on	2019-04-19	1555651992
146	1	on	2019-04-20	1558326244

Figure 7 - Simulated timeseries data set

A python script runs as a scheduled task daily at a user specified time (daily at 12.10 AM) to model these collected data using ARMA model to predict the next possible event occurring time for the selected item and event. This script retrieves the required time series data by querying the database for the electrical item (kitchen light) and its desired status (ON). The query is limited to retrieve data related to the last 60 days, accumulating to the last two months for a more reliable outcome. Once these data are retrieved, the script tries to clean the data set by removing outliers (noise removal). This is an essential part it a machine learning algorithm as certain data can be considered as noise having huge difference from a normal, standard data set. If these outliers are not removed, the final outcome can be erroneous. Below are two diagrams visualizing these collected data in a graphical manner. First figure is displaying the entire raw data set retrieved from the database as it is which is having few outliers. Second figure shows a graph of a subset of the retrieved data from the database having these outliers removed. X- axis of the graph is "***day"*** which has past data where Y-axis of the graph is the "***UNIX timestamp***" (double value) for the event occurrence.

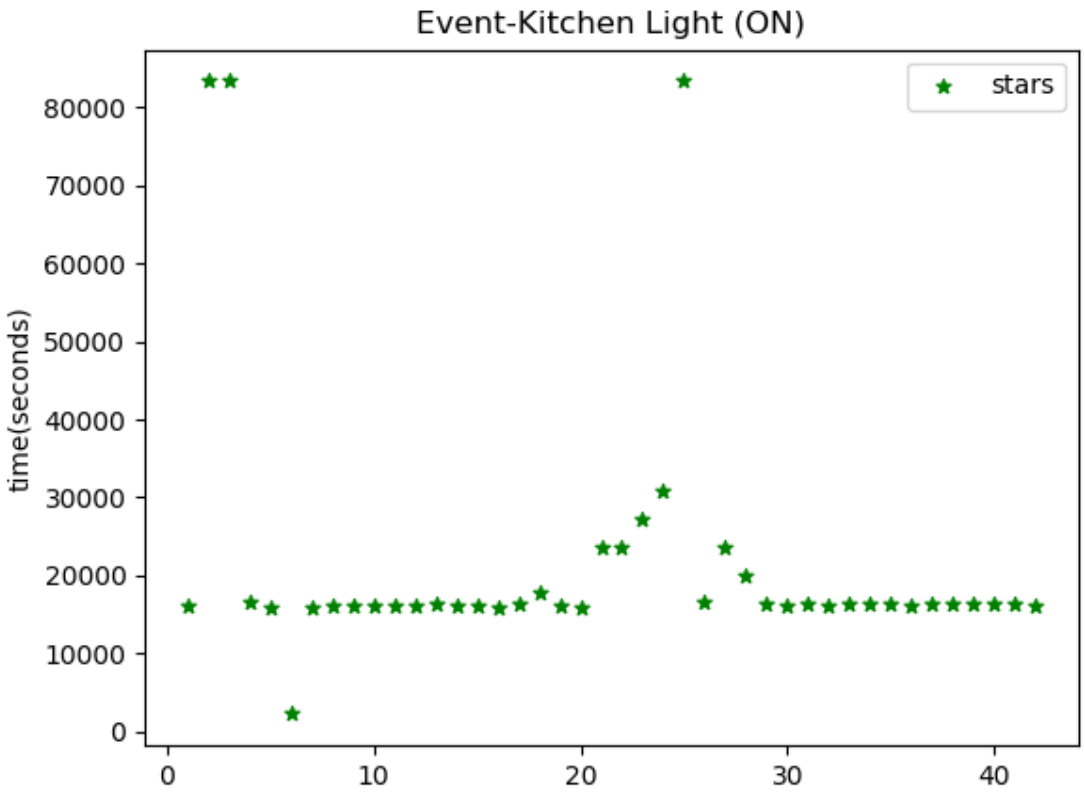

Figure 8 - raw timeseries data visualization with outliers

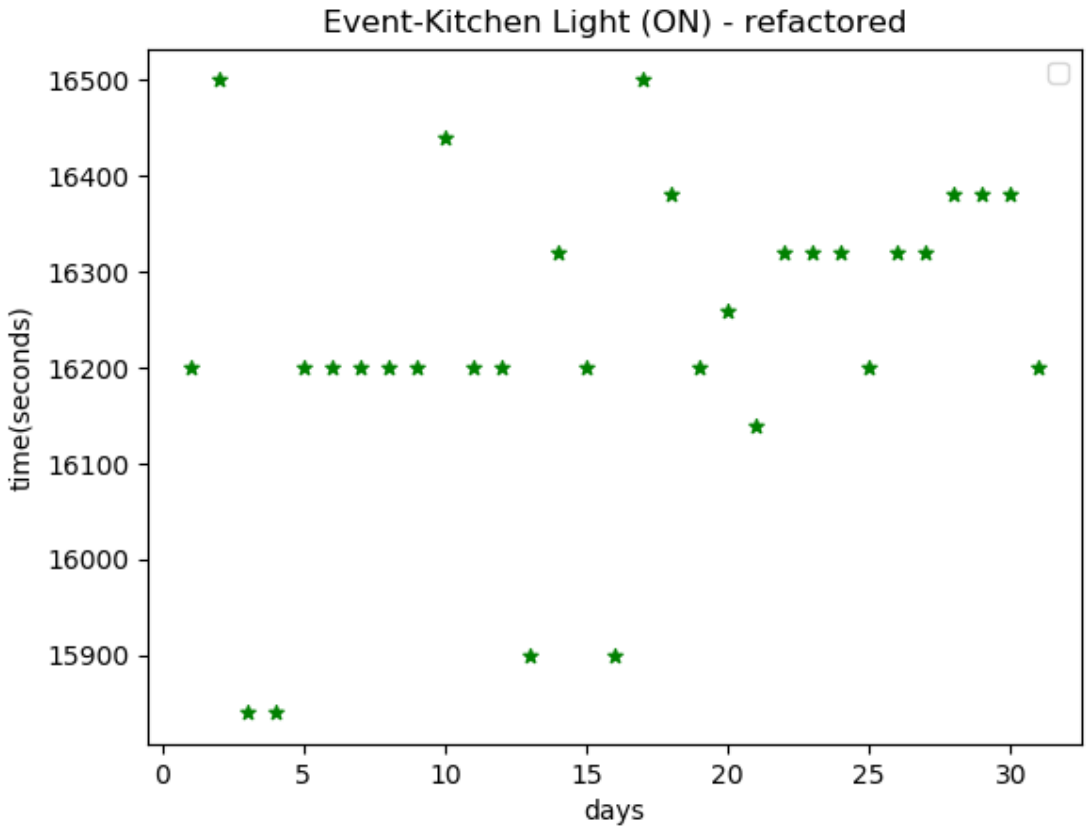

Figure 9 - Timeseries data visualization without outliers

This cleansed data is then fed to the ARMA modelling python implementation to forecast the next event occurring time and result is persisted in the database. These predictions are visible in the web portal. Correspondingly, these predictions are sent to users' smart phone, to the smart home application, in which the user accepts or reject the predictions. Below image is a screen capture from the mobile application.

User acceptance or rejection of the predicted values is captured from the mobile app and persisted in the database. These data is again used in the next cycle of the algorithm running.

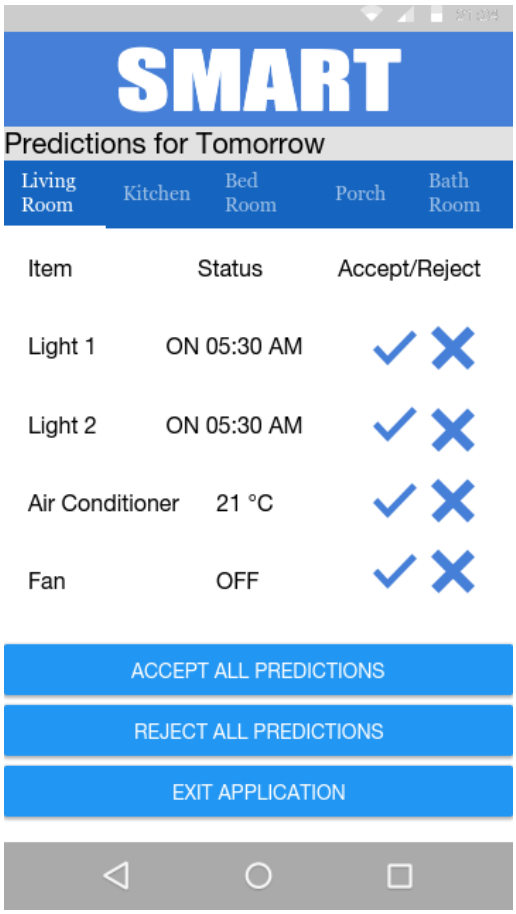

Figure 10 - Smart home mobile app screenshot

5.1 Results

Using ARMA model for forecasting time for event in the smart home use not productive initially given that the entire set of raw data was used as inputs for the algorithm without any cleaning. Later once the outliers were removed, much acceptable results were obtained. These results vary from one event to another but by visualizing the data, it was easy to register the acceptability of the final result which mapped to a certain accuracy level. Below timeseries data set and the final outcome can be used to prove this statement.

Problem statement: when does the next event of kitchen light switch ON (in the morning) should occur?

Inputs: simulated data (timestamp) for the event of kitchen light switching ON (in the morning)

Process: remove outliers (if any) and feed cleansed data to ARMA algorithm

Output: predicted time for kitchen light switch ON

ARMA algorithm Execution Results without data cleansing

Input (raw data):

[4:30:00, 23:10:00, 23:10:00, 4:35:00, 4:24:00, 0:37:00, 4:24:00, 4:30:00, 4:30:00, 4:30:00, 4:30:00, 4:30:00, 4:34:00, 4:30:00, 4:30:00, 4:25:00, 4:32:00, 4:55:00, 4:30:00, 4:25:00, 6:33:00, 6:33:00, 7:35:00, 8:35:00, 23:10:00, 4:35:00, 6:33:00, 5:33:00, 4:33:00, 4:30:00, 4:31:00, 4:29:00, 4:32:00, 4:32:00, 4:32:00, 4:30:00, 4:32:00, 4:32:00, 4:33:00, 4:33:00, 4:33:00, 4:30:00]

Output:

[6:54:34]

ARMA algorithm Execution Results with data cleansing

Input (raw data):

[4:30:00, 23:10:00, 23:10:00, 4:35:00, 4:24:00, 0:37:00, 4:24:00, 4:30:00, 4:30:00, 4:30:00, 4:30:00, 4:30:00, 4:34:00, 4:30:00, 4:30:00, 4:25:00, 4:32:00, 4:55:00, 4:30:00, 4:25:00, 6:33:00, 6:33:00, 7:35:00, 8:35:00, 23:10:00, 4:35:00, 6:33:00, 5:33:00, 4:33:00, 4:30:00, 4:31:00, 4:29:00, 4:32:00, 4:32:00, 4:32:00, 4:30:00, 4:32:00, 4:32:00, 4:33:00, 4:33:00, 4:33:00, 4:30:00]

Cleansed data:

[4:30:00, 4:35:00, 4:24:00, 4:24:00, 4:30:00, 4:30:00, 4:30:00, 4:30:00, 4:30:00, 4:34:00, 4:30:00, 4:30:00, 4:25:00, 4:32:00, 4:30:00, 4:25:00, 4:35:00, 4:33:00, 4:30:00, 4:31:00, 4:29:00, 4:32:00, 4:32:00, 4:32:00, 4:30:00, 4:32:00, 4:32:00, 4:33:00, 4:33:00, 4:33:00, 4:30:00]

Output:

[4:29:58]

Chapter 6: Conclusion

The homes in near future can be expected to come with built in “smart home” capabilities with the evolving technologies and research which are carried on by especially home manufacturers, smart devices developers and information technology experts. During this study, recording, analysing and predicting user activities in a household is given the main priority. In order to predict the users’ next activity, machine learning is used with recorded past data to perform a better user profiling based on his/her activities. ARMA model is used to model the timeseries data and forecast next values.

Though there are many home automations solutions available, this study has focused on combining machine learning with the home automations system to provide a more sophisticated solution with a user centric scenario. The ARMA model gives acceptable predictions for the users’ next activity within the household. For the simplicity of the use case for this study, only switching ON/OFF lights are considered when presenting results, but this model can be used to extend the capabilities of the smart home system with ease such as controlling cooling systems.

Future Work

Hence, this study can be further extended to address other electronic appliances such as controlling irrigation systems, cooling systems, surrounding maintenance. Even though the smart home discussed here can provide acceptable results for future event prediction in terms of the time of said events occurrence, the accuracy of the provided result is still debatable. Hence, it is suggested that a better approach needed to be identified to calculate the accuracy of the prediction system.

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