Decision Support Approach to Domestic Energy Monitoring System

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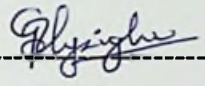
Declaration

I declare that this thesis is my own work and has not been submitted in any form for another degree or diploma at any university or other institution of tertiary education. Information derived from the published or unpublished work of others has been acknowledged in the text and a list of references is given.

G.A.G.K.Abeysinghe ---------- 

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Dedication

I dedicate this thesis to my beloved parents who have never failed to support me, throughout my life. They have thought me that any task can be accomplished by taking a step at a time.

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I wish to express gratitude to my project supervisor Mr.Saminda Premaratne who untiringly shared his knowledge, provided precious guidance, encouragement, advices and assistance to complete the project successfully.

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Abstract

This thesis presents a new decision support approach to energy control and monitoring system of domestic appliances. In the modern world, people are rapidly turning to technology as a fast and cost-effective way of improving quality of daily living. This primary goal is to address the needs of the end user by employing networked low-power sensors sensitive to the environment, so it can be altered to their liking.

The proposed system consists of following steps: energy control and monitor, data analysis and data predictions. This research will present the design and implementation of a practical and simple smart home system, which can be further extended. The system is based on: group of sensors, Arduino UNO with unit and WIFI as a communication protocol.

These devices can be easily controlled via user-friendly interfaces via web applications. The web applications are available for Consumers and Administrative Staff. Those web applications represent to the users are statistical data by using Google charts.

Data analysis part has done using Data Mining techniques such as clustering and regression analysis. Sample data has been generated by using Test Data Generation Tool is DTM tool. Clustering and Regression Analysis has been done by using Rapid Miner Tool. Data prediction was done by using Regression Analysis technique.

The main advantage of the proposed system is that it is a sensible, secure and easily configurable system that provides end users with a cost-effective energy consumption solution.

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Chapter 1

Introduction

1.1 Prolegomena

Due to the rapid advances in wireless communication and information technologies it is now possible to embed various levels of smartness in the home. These smart homes are ones that can interact intelligently with their inhibitors to provide comfort and safe living. This interaction may range from simple control of energy and mobile agent based services.

Smart home is a house that uses technology to monitor the environment with the help of various sensors, control the electrical appliances and communicate the outer world. Smart homes can also refer as intelligent homes or automated homes. With the recent expansion of communication networks, smart home applications can be further enhanced with new dimension of capabilities that were not available before. The wide spread of wireless networks in our daily life is enabled by the communication standards such as WiFi[1], Bluetooth[2], Zigbee, RFID and mobile technologies. This proposed system is a Decision Support Approach to the Domestic Energy Consumption. There are two main parts in this title of the research are Decision Support part and Energy Monitoring and controlling part. The Decision Support module includes data analysis activities and Energy controlling and monitoring module includes hardware and software. Despite numerous research in smart home technology, efficiency and security of energy consumption and control appliances has been a research challenge. This research presents our work on wireless technology and web technology based approach to secure energy control and monitoring system with a higher level of efficiency. This chapter present the background and motivation of the research, hypothesis, objectives, problem statement, smart home approach and the structure of the rest of the thesis.

1.2 Background and motivation

This application based on the information of Lanka Electricity Company (Pvt) Ltd (LECO)[3]. Lanka Electricity Company (Pvt) Ltd is a private limited liability company incorporated in 1983 for Distribution of Energy. Present shareholders of LECO are CEB, UDA, Government Treasury and four Local Authorities (LA). The unique achievement of LECO as a successful business venture was its ability in meeting a challenge in attracting foreign funding for the network improvements.

LECO serve 570000 customers out of which 87% is domestic. Industrial and Commercial customers amounts to 12% and the religious customers are the balance 1%. Out total energy sales is approximately 1000 GWh with an installed capacity of 369MW at LECO energy purchase nodes. 44% if the energy sold is consumed by the domestic customers and 53% by the commercial and industrial customers. Balance 3% is consumed 1% by religious customers and 2% for street lights. 50% of LECO customers consumes below 150kWh per month, 10 consumes below 600kWh per month and 90% below 100kWh. LECO network load experience a day peak of approximately 280MW and a night peak of approximately 300MW.

In order to keep an efficient system with minimum faults, LECO carries out routine maintenance of all transformers, high voltage (11 kV) & low voltage (230V) lines and all the other equipment of the distribution system. LECO always gives a major attention to reduction of energy losses in the distribution system. LECO is totally aware that reduction of energy losses in the distribution system will help to save significant financial savings on power generation of the country. It also helps to minimize emissions due to power generation which is good for the environment. LECO has the benchmark of maintaining the energy loss less than 5%. LECO target is to attend all service calls within a time of 30 minutes. LECO is a dedicated team in the customer service centers to attend to such breakdowns on a 24/7 basis. And this process is well monitored to minimize the electricity outage duration. LECO staff is always dedicated to support for all types of customer issues (technical, legal, administrative, etc.) related to the electricity distribution system. Customers have the provision to access LECO management or relevant staff through telephone, fax, e-mails, letters or walk through visits. LECO is always trying to supply a reliable and safe supply of electricity to their customers all the time. We are

carrying out a system development process that works effectively in order to maintain the reliability. Further, LECO is always taking the performance statistics to take detective and preventive actions against system faults.

There are seven branches belong to LECO which are Kotte, Kelaniya, Moratuwa, Galle, Kalutara, Negombo and Nugegoda. Those all branches are having Customer Service Centers (CSC). The maintenance teams, technical teams are working in these CSCs. The information is based on the Kotte branches' consumers.

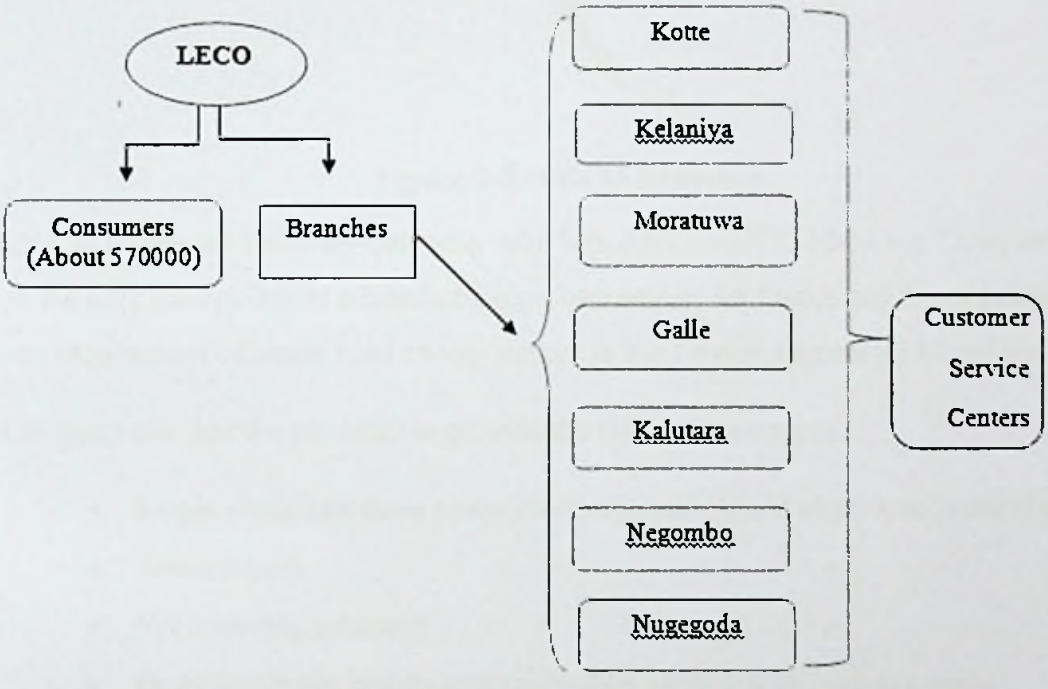

Figure 0-1-Perspective of end users

Figure 0-2: LECO Branches

Further, LECO has a subsidiary company which is ANTE LECO Metering Company (Pvt) Ltd. This is the only Energy Meter Manufacturing Company in Sri Lanka and is committed to supply the total requirement of house hold energy meters to the Ceylon Electricity Board and LECO.

The Company also has the potential to provide the following services,

- Single phase and three phase electronic meters and electromechanical meters.
- Smart meters.
- Net metering solutions.
- Providing meter testing and calibration facility with high accuracy.

The proposed system is a web based application with compatible with mobile targeting on LECO consumers and LECO staff. There are two types of web applications are Customer portal and Administrative portal. Users are accepting by the system through an authentication process. There is a special authentication process for Customer portal. It is called dual authentication process and it is a secure method to access. LECO consumers will be benefited through this system as below.

1. Monitor the energy consumption of home appliances
2. Control the devices which sensor available remotely
3. Compare the power consumption by analyzing statistical data through the system

4. Identify the appliances which are consuming high energy and ability to replace the appliances
5. Compare the consumption units and bill amount with previous few months.

LECO will be benefited as below,

1. Monitor the power consumption of consumers
2. Quick tracking the unauthorized energy consumption statistically and geographically
3. Able to suggest energy saving tips by analyzing real time energy consumption information
4. To serve best customer service

1.3 Problem statement

Smart Home Technology is fast emerging technology which involves interaction among things through internet without human interference. It has made human life easier and comfortable. Now-a-days digital devices in home are increasing rapidly due to which there is a need of accessing and controlling the devices remotely.

Today people are looking at ways and means to better their life-style using the latest technologies that area available. Any new facility or hope appliance that promises to enhance their life-style is grabbed by the consumers. The more such facilities and appliances are added, it becomes inevitable to have easy and convenient methods and means to control and operate these appliances. Conventional wall switches are located in different parts of a house and thus necessitates manual operations like to switch on or off these switches to control various appliances. It gets virtually impossible to keep track of appliances that are running and also to monitor their performances.

Most of the electricity consumers are not satisfying about their energy readings on electricity meters. They are directly inquiring to the electricity providers and electricity providers are giving solution as meter testing to the consumers. This process is not transparent and consumer has to expend their money for that service. Therefore, I define the research problem as inadequate attention given to implement an energy consumption monitoring system to monitor

and control home appliances integrating with decision support approach that ability to use in mobile devices and laptop and desktop computers.

1.4 Hypothesis

Design and implement an energy control and monitoring system to control appliances and monitor the energy consumption integrating with decision support approach and mobile technologies and web technologies.

1.5 Objectives

To understand how an in-home energy display (IHD) may affect the home residents habits, encouraging positive changes in terms of energy efficiency and environment-friendly behaviors, it is important to organize the regular user behaviors related to energy consumption (or saving) .And further, to understand the interaction paradigms lying at the basis of currently available solutions. The rest of things provide a quick overview of regular home user behaviors, with respect to energy saving, and the possible saving strategies that IHDs can feat/motivate.

There are two types of objectives such as problem related and solution related.

(i) Critical review the state of the art of smart home technology and Internet of Things (IOT)

(ii) To do in depth study of wireless technologies, sensors, web technologies and mobile applications with a particular emphasis on energy control and monitoring systems

(iii) To develop a new system as a solution to the LECO and their consumer's energy consumption

(iv) To evaluate the energy consumption of selected domestic appliances

(v) To analyze the home appliances' energy consumption and monthly consumption units of consumers' homes

(vi) To predict energy consumption in next few months using existing data

(vii) Identify energy consumption patterns in home appliances

1.6 Energy control and monitoring approach

Changes in the users' behavior are also another important factor in relation to the improvement of the energy performance of home. Recently, users have become more conscious of energy usage in homes and are increasingly interested in real-time energy monitoring and controlling devices and tools. Furthermore, the market for residential energy management is poised to grow dramatically due to increased users' demands and new governmental and industry initiatives. Different energy efficient routing protocols and energy management systems have been proposed to provide information about energy usage patterns. They offer users actionable information and control features while ensuring ease of use, availability, security, and privacy.

1.6.1 Users

There are two web applications for LECO consumers and LECO Administrative staff. The hardware unit will be plug into LECO consumers' homes. And analysis data will be used by LECO managerial staff. Basically, two types of users are interacting with the system as,

- LECO administrative staff
- LECO consumers

1.6.2 Input

Mainly, web applications inputs can be defined as below.

- Username, password (authentication keys)
- Appliances details (name, capacity, location, purchased date, etc)
- Customer details (electricity account no, name, location, contact no, e-mail address, etc)
- Push ON/OFF button
- Choose menu item

Hardware unit has inputs as below.

- Appliances' Ampere
- Appliances' Watt

1.6.3 Output

Web applications output as below.

- Notifications (appliance ON or OFF, etc)
- Statistical details / graphs
- Special news from Electricity Company
- Summarized electricity consumption units in previous few months ago

Hardware units' output as below.

- Appliances' consumption
- Consumption period
- Appliances ON/OFF status

1.6.4 Process

The hardware unit is plugging to the home and appliances' consumption will be saved in a centralized database is Oracle database. The customer web portal and administrator portal have been hosted in WAMP server and statistical data is represent on the web in Google charts. Advanced analysis results can be generated using Rapid miner tool will be useful to the LECO managerial staff.

By using customer portal, LECO consumer ability to,

- Enter into the system
- Select the menu
- Select the relevant appliance
- Turn ON/OFF the appliance using push button
- Check the consumption, check the statistics
- Logout

By using administrator portal, LECO staff ability to,

- Log into the system
- Get statistics of energy consumption and ability to check real-time consumption of consumers

- Logout

1.6.5 Features

The features are related on the hardware unit and web applications. Those features are as below.

- Reduced Installation costs – low cost and high accuracy featured components are integrated.
- Internet Connectivity – LECO areas are not located in rural. Most of the customers are nearby main cities. Internet coverage is trusted in those areas.
- Scalable and Expandable – hardware unit can be expandable by using advanced components and new sensors.
- Security - enabled confidentiality authentication process.
- User friendly – ability to understand the details on web application and ability to use easily.
- Accuracy – information of the system saving into database in every moment. No data losses.

1.7 Summary

This chapter gave an overall picture of the entire project presented in this thesis. As such we described the background and motivation, problem definition, hypothesis, objectives and brief overview of the solution. The rest of the thesis is organized as follows. Chapter 1 critically reviews the literature on Smart Home Technology and identify the research problems. Chapter 3 is about the Smart Home Technology for recognition of wireless technology and sensors and Android technology. Chapter 4 present our new approach to use wireless, sensors and web and Android technologies. Chapter 5 and 6 describes the design and implementation respectively. Chapter 7 is on evaluation of the new solution. Chapter 8 concludes the research with a note on further work.

Chapter 2

Developments in Smart Home Systems

2.1 Introduction

Chapter 01 gave a comprehensive description of the overall project described in this thesis. This chapter provides a critical review of the literature in relation to developments and challenges in Smart Home Systems. For this purpose, the review of the past researches have been presented under three major sections namely, early developments, achievements and unsolved problems. At the end, this chapter defines the research problem as the inadequate improvements in the current smart home systems and identifies the wireless technologies, sensors, microcontrollers and mobile technologies that can be used to address the problem.

2.2 Related Work

Nichols and Myers have been studied on that the possibility to auto generated interfaces for controlling appliances on a smart phone [4]. This study is based on the mobile phone applications than can be controlled appliances. They were able to generate interfaces for most of the devices and control appliances. The limitation of this study to generate interfaces that are customized to users and the devices they used. The enhancements of the research are generating interfaces with compatible with the appliances.

Michel and fellows have been done a research on user-led innovations and participation processes[2]. This research is based on several case studies in the field of renewable energy technologies such as solar collectors, bio heating systems and sustainable building technologies. The researches have been got involved the users with behavioral questions, technological problems and instructional conditions. But the limitations were un-experienced persons and lack of technology in this field. The researchers want to point out that under certain conditions a higher degree of user involvement or self-building groups might lead to a successful mode of innovation of certain energy technologies.

The research on web services for integration of smart houses in the smart grid has been done by Warmer and fellows[3]. This research is based on web services that provide a common framework that allows data to be shared and reused across applications, enterprises and community boundaries. The limitations on this research is the system was done according to the

ongoing smart house/smart grid project and they hope to build some business applications and roll out in three different European field trials as their future work.

Robles and Kim have been done a study on security in smart home development[4]. This study is based on related smart home systems, technologies, software and the current security in the field. The authors have been studied the tools related to smart home security. The important issue is the security in smart home appliances. So therefore, many more researches required to protect smart home appliances.

A qualitative field study on how householders interact with feedback from smart energy monitors has been done by Hargreaves and colleagues[8]. This study is based on qualitative evidence from interviews with 15 UK householders trailing smart energy monitors of differing levels of sophistication. This paper represents that some limitations such as certain appliances could not be discarded, energy monitor unwelcome, family negotiations about consumption provoked by the monitors and policy context is unsupportive. There are many challenges in technological and production areas. Finally, this paper discusses the further researches and policy. More researches are required to implement expansion of renewable energy, reduce energy consumption and support to change the domestic energy consumption patterns.

Piyare and Tazil have been done an implementation on Bluetooth based home automation system using cell phones[2]. This research is based on Bluetooth technology. The authors have been implemented a home automated system based on Bluetooth technology using cell phones. This solution has implemented Symbian OS cell phones only. Furthermore, studies are required to implement a GUI application written in Java.

Shin and Hwang have been experimented and proven by tested that intelligent energy information service[9] This study is based on a multi home environment which can share energy consumption data with its neighbors. This system provides services such as energy consumption monitoring, remote control functionality of home appliances and intelligent services including statistics and energy consumption comparison with neighbors. But, some technical issues such as traffic management and processing speed should be considered. Furthermore, privacy and security issues should be considered.

AI-Daraiseh and colleagues have been done a study on energy management system for educational buildings[10]. This study is based on consumption of energy in King Saud University which is a higher education institution (HEI) building. The authors have been implemented first phase of the system using sensors to optimize the energy consumption in HEI buildings and reduce carbon dioxide emission (CO_2). System has identified the hidden energy waste in laboratories and offices and takes appropriate measures to optimize energy consumption.

Morris and fellows have been done a research on smart home technologies to assist older people to live well at home[11]. This research is based on elderly people who are accepted smart home technologies. This study has identified that older adults and health professionals considered smart home technologies to be beneficial. It is possible that improvements in safety, security and independence may also have a positive effect on quality of life in the elderly people. Privacy needs to be considered in the design of future smart home technologies. Future studies may need to consider multiple factors such as finances, social circumstances; family and level of independence are considered when a person chooses where they will live. Furthermore, this study was the decision to limit the search to articles published in English.

Sung and Lin have been implemented a smart LED lighting system[12]. This implementation is based on Android mobile devices. The authors have been implemented an application to power monitor for home appliances. It consist of controller (server), touchpad (HCI), digital multi-meter, IR-module and lighting control module. This research has done by the minimization of the squared error through a self-adaptive weighted data fusion algorithm that is the limitation is heat effect on the LED color. So therefore, more researches required to issue of LED cooling.

An analysis of the smart home literature has been done by Solaimani and fellows[13]. The analysis moves from exploration towards the exploitation of Smart Home Concept and it is based on a coherent body of knowledge that covers technological, organizational, economical and business. The authors do not include all the existing publications related to the Smart Living. Smart living concepts are not commercially exploited makes it clear that there must be plenty of strategic, organizational and financial issues that require further attention.

Pierleoni and colleagues have been done a research on an Android based heart monitoring system for the elderly and for patients with heart disease[14]. The research has been done based

on elderly people and patients with Cardiovascular Disease (CVD). All the data about the patient's health status can be stored in an online database. But the current knowledge of the long term consequences of certain Heart Rate (HR) features and HR Variability (HRV), for example, circadian regulation is limited. And prolonged use of the application did not evidence bugs or unexpected system crashes.

A research on Smart Home System based on sensor technology has been implemented by Davidovic and Labus[15]. The research is based on group of sensors, Rasberry Pi device as a server system and Bluetooth as a communication protocol. The system uses by Android devices. The main disadvantage of the system is Raspberry PI device has defined maximum number of directly connected sensors. This limitation can be overridden by adding extensions to Raspberry PI device, which will allow users to connect more sensors to it. This system is also easier to setup and configure for small to medium size homes, because of the limitation of Bluetooth signal. This disadvantage can be overridden by setting multiple Bluetooth receivers in the smart home.

Lee has been done an experiment and proven by tested on testbed in the university is advancing building energy management system to enable smart grid interoperation[16]. This research is based on service data, service interface, intelligence and security of smart grid. The system is an enhancement in the existing energy monitoring system (EMS). The new system named as Premises Automation System (PAS). There are many challenges to energy transactions in future. So therefore, many more researches required to advancement of EMS as a micro grid platform that can support energy transaction.

2.3 Problem Definition

Based on the literature review has identified various unsolved problems including security, efficiency and reliability of smart home systems and modern trends and future challenges. Table 2.1 summarizes the achievements and the limitations of the key research discussed in this chapter.

Research	Technology	Key benefits	Limitations
1. Controlling Home and Office Appliances with Smart Phones(Jeffrey Nichols and Brad A. Myers - 2006)	Smart phone technology, User interface design tools	Were able to generate interfaces for most of the devices and control appliances	Customizable interface generation
2. User-led innovations and participation processes(Michael Ornetzedera, Harald Rohracher - 2006)	Case study	Ability to find challenges on this field.	Not enough user involvement in this field.
3. Web services for integration of smart houses in the smart grid(Warmer .et al - 2009)	Web services, SOA	Integrate smart houses in smart grid	Limited specification
4. Security in Smart Home Developments(Robles and Kim - 2010)	Security tools	Ability to find security challenges	Network security
5. A qualitative field study of how householders interact with feedback from smart energy monitors	Survey, Interview questions, energy monitoring, smart metering	Identify significant implication for future research and policy	Consumer's behavioral changes

(Hargreaves and et al. - 2010)			Symbian OS cell phones only support Python scripts
6. Bluetooth based home automation system using cell phones (Piyare and Tazil - 2011)	Bluetooth, Arduino BT, Relays, home appliances	Low cost, flexible, secure	
7. Intelligent energy information service based on a multi-home environment (Shin and Hwang - 2012)	Energy consumption data	Ability to identify energy consumption of appliances	Traffic management, Processing speed
8. Energy management system for educational buildings (AI-Daraiseh and et. al - 2013)	Sensors, SOA, Software	Identified the hidden energy waste	Timetabling system
9. Smart home technologies to assist older people to live well at home (Morris and et. al - 2013)	Survey	Older adults and health professionals considered smart home technologies to be beneficial	Limited related researches
10. Design and Implementation of a Smart LED Lighting System Using a Self - Adaptive Weighted Data Fusion Algorithm (Sung and Lin - 2013)	Wireless technology, LED lighting systems, controllers, algorithms	Control the home appliances remotely	Heat effect on LED colors
11. An analysis of the	Survey	Identify Smart Living	Not enough publications

smart home literature (Solaimani and et .al - 2013)			
12. An Android based Heart Monitoring System for the elderly and for patients with Heart Disease (Pierleoni and et. al -2014)	Android, algorithms, SMS, database	Detect stress states, classify arrhythmia events and calculate energy consumption.	Current knowledge of some certain diseases is limited
13. Smart Home System based on sensor technology (Davidovic and Labus -2015)	Sensors, RasberryPi, Android, Bluetooth	Sensible, secure and easily configurable	RasberryPi device has defined maximum number of directly connected sensors, limitation of Bluetooth signal
14. Advancing building energy management system to enable smart grid interoperation (Eun-Kyu Lee - 2016)	Smart grid, algorithms, sensors, network, security	Efficient energy management	Energy transactions

Table 2-1: Summarizes the achievements and the limitations

According to Table 2.1 despites many solutions are available for smart home systems, some of them are rather expensive and utilize too much of resources such as RasberryPi. Therefore, we cannot go for a customized solution of the existing some approaches. Instead should go for a low-cost solutions that machines with the need of small systems.

We intent to address the above problem using web-based technology. This is because, many researchers have shown suitability of smart home technology even for accessing the very large systems. We have noticed that limited research in Smart Home with technology has been recorded in the literature. More important as shown in Table 2.1 smart home system has been the

most popular and lightweight technology for accessing any large system through mobile device. Details of the technology behind the solution will be discussed in Chapter 03.

2.4 Summary

This chapter presented a comprehensive literature review on the smart home research and identified the research problem as the inadequate attention to reliability of smart home technologies. We also identified the web technology to address the above problem. Next chapter will discuss the technology to be used for our solution.

Chapter 3

Technology Adopted - Smart Home Technology

3.1 Introduction

This chapter describes the technologies are using to this research. The three basic building blocks of this project are Arduino microcontroller, Web application server and Android application. The basic idea is to control different appliances and devices using the mentioned components. Sensors will be used to sense different factors such as measure current and send corresponding messages to the android application. On receiving alert messages the user can instruct the devices to behave accordingly. Web server will help the user to access the devices remotely. Such an application is very useful but less secure, anyone can share that application or access it if no security is provided. So to make the app more secure we can provide a password protection for the android app. To implement such a system following technologies joint with it.

1. Arduino
2. WIFI
3. Mobile Platform
4. PHP
5. Relays
6. Current Sensor
7. Ethernet Shield
8. Oracle
9. WAMP Server
10. DTM Data Generator tool
11. Rapid Miner Tool

3.2 WIFI

Wireless Fidelity (WiFi) is a common term that refers to the IEEE 802.11 wireless communication standard for wireless local area networks (WLAN) in the 2.4, 3.6 and 5 GHz frequency bands. Network users, when using WiFi technology, can move around without restriction and access the network from almost anywhere. Also it can provide a cost effective network setup for hard-to-wire locations such as old buildings. Two types of devices are

considered in the WiFi standard: an access point (AP) and a wireless device which could be a laptop equipped with a wireless network interface. The main function of an AP is to bridge the information between the fixed wired network and the wireless network. An AP can support up to 30 wireless devices and can cover a range of 33–50 meters indoors and up to 100 meters outdoors. The wireless devices can be possibly connected together using infrastructure topology or an ad hoc mode topology. The infrastructure topology is sometime called an AP topology since the wireless network consists of at least an AP and a set of wireless devices. In this topology, the system is divided into basic cells, where each cell is controlled by an AP.

3.2.1 ESP8266 WIFI Module

ESP8266 is a chip. It with which manufacturers are making wirelessly networkable micro-controller modules. More specifically, ESP8266 is a system-on-a-chip (SoC) with abilities to 2.4 GHz Wi-Fi (802.11 b/g/n, supporting WPA/WPA2), Inter-Integrated Circuit (I^2C), general-purpose input/output (16 GPIO), analog-to-digital conversion (10-bit ADC), I^2S interfaces with DMA (sharing pins with GPIO), Serial Peripheral Interface (SPI), UART (on dedicated pins, plus a transmit-only UART can be enabled on GPIO2), and pulse-width modulation (PWM). It services a 32-bit RISC CPU based on the Tensilica Xtensa L106 running at 80 MHz (or overclocked to 160 MHz). It has a 64 KB boot ROM, 64 KB instruction RAM and 96 KB data RAM. External flash memory can be accessed through SPI.

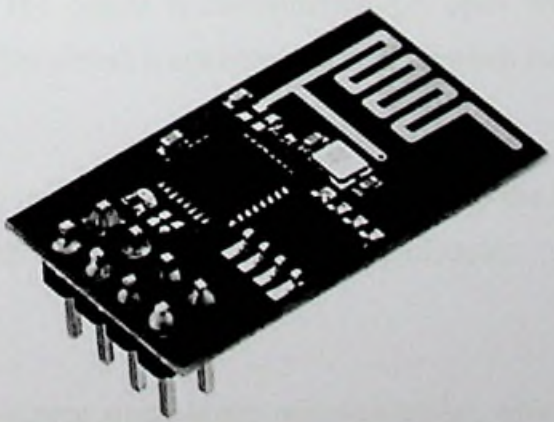

Figure 0-1:ESP8266 WiFi Module

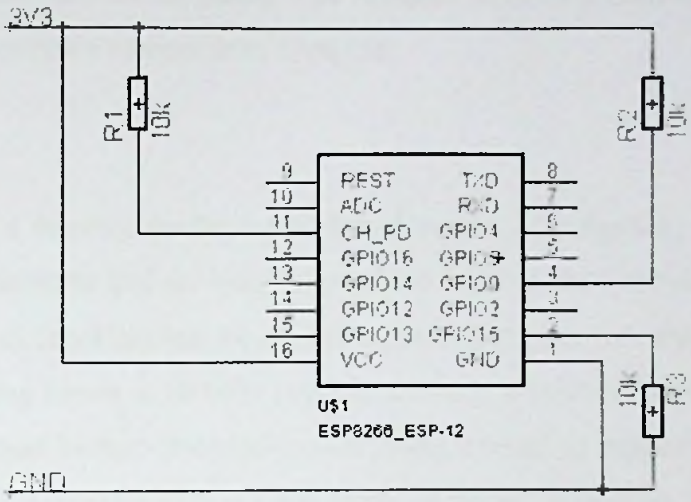

Figure 0-2:ESP8266 WiFi Module- Datasheet

This WIFI module has been used to develop the unit. It was connected with the devices. But finally, this module was not necessary for the unit and it was replaced by Ethernet Shield.

3.3 Relays (5V)

A relay is an electrically operated switch. It is mainly used to control higher voltage circuits with lower voltage. The 'control' and 'controlled' circuits are electrically isolated from each other. Since relays are switches, the terminology applied to switches is also applied to relays; a relay switches one or more poles, each of whose contacts can be thrown by energizing the coil.

1) Normally-Open (NO): The circuit is disconnected i.e. open when the relay is inactive.
2) Normally-Closed (NC): The circuit is connected i.e. closed when the relay is inactive.

This module has been used to connect electrical appliances into the hardware unit. Appliances has been ON/OFF commands were controlled through this module.

3.4 Arduino

Arduino is a popular open-source single-board microcontroller, which is designed to make the process of using electronics in multi-disciplinary projects more accessible. The hardware consists of a simple open hardware design for the Arduino board with an Atmel AVR processor and on-board input/output support. The software consists of a standard programming language compiler

and the boot loader that runs on the board. The Arduino board is a hardware interface allow to control and monitor hardware devices with computer.

3.4.1 Arduino UNO

The Arduino Uno is a microcontroller board based on the ATmega328. Arduino is an open-source, prototyping platform and its simplicity makes it ideal for hobbyists to use as well as professionals. The Arduino Uno has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with an AC-to-DC adapter or battery to get started.

The Arduino Uno differs from all preceding boards in that it does not use the FTDI USB-to-serial driver chip. Instead, it features the Atmega8U2 microcontroller chip programmed as a USB-to-serial converter.

"Uno" means one in Italian and is named to mark the upcoming release of Arduino 1.0. The Arduino Uno and version 1.0 will be the reference versions of Arduino, moving forward. The Uno is the latest in a series of USB Arduino boards, and the reference model for the Arduino platform.

Features of the Arduino UNO:

- Microcontroller: ATmega328
- Operating Voltage: 5V
- Input Voltage (recommended): 7-12V
- Input Voltage (limits): 6-20V
- Digital I/O Pins: 14 (of which 6 provide PWM output)
- Analog Input Pins: 6
- DC Current per I/O Pin: 40 mA
- DC Current for 3.3V Pin: 50 mA
- Flash Memory: 32 KB of which 0.5 KB used by bootloader

SRAM: 2 KB (ATmega328)

EEPROM: 1 KB (ATmega328)

Clock Speed: 16 MHz

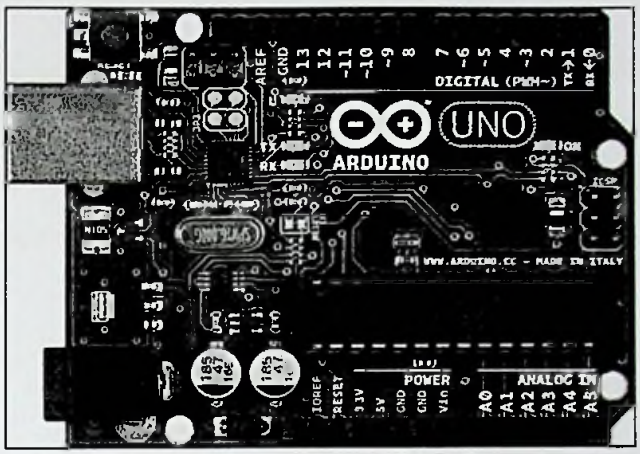

Figure 0-3: Arduino UNO Board

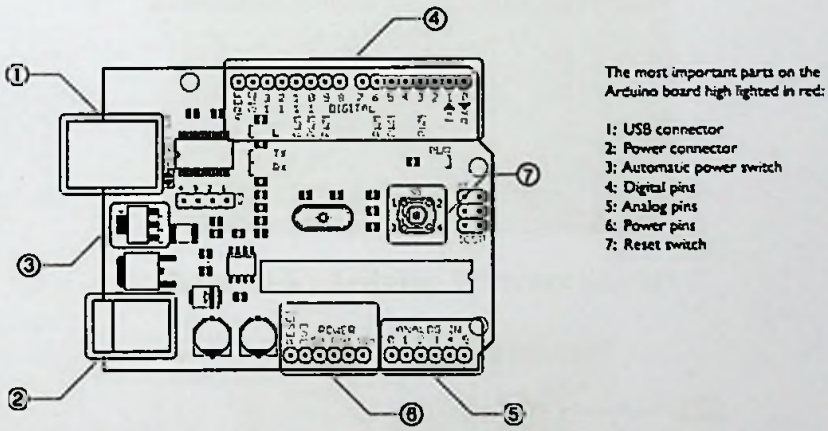

Figure 0-4: Arduino UNO – Datasheet

This component is the heart of unit. It is a microprocessor. All the communications are happening through this component. The hardware program has been uploaded into this board. Every commands are working through this module.

3.5 Arduino Ethernet Shield

The Arduino Ethernet Shield allows to easily connect Arduino unit to the internet. This shield enables Arduino unit to send and receive data from anywhere in the world with an internet

connection. It can use to do control appliances remotely from a website, to control robot remotely from a web site or ring a bell every time get a new message from messenger, twitter, such applications, etc. This shield opens up endless amounts of possibility by allowing to connect the unit of network to the internet in no-time flat.

There is also an on-board micro SD slot which enables to store a heck-of-a-lot of data, and serve up entire websites using just Arduino unit. This requires the use of an external SD library, which does not come bundled with the software. The board also has space for the addition of a Power over Ethernet (PoE) module, which allows to power Arduino unit over an Ethernet connection.

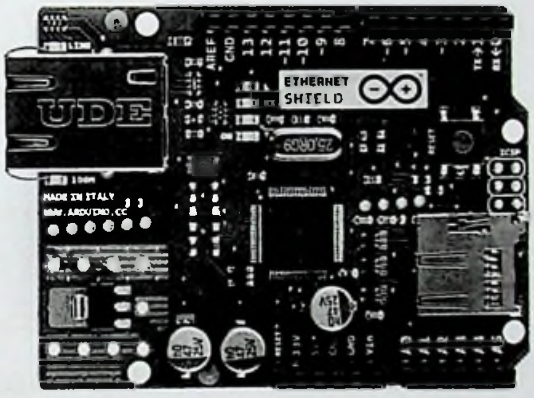

Figure 0-5 : Arduino Ethernet Shield

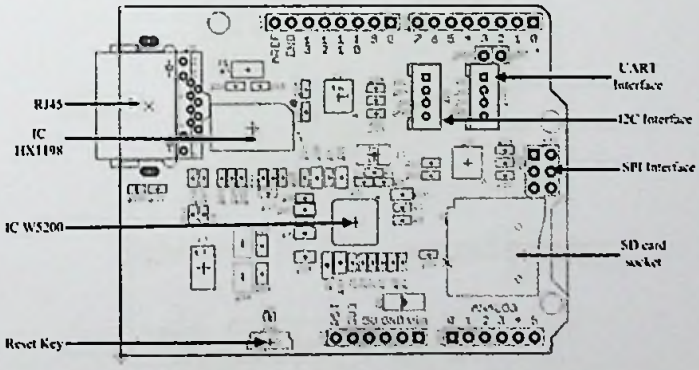

Figure 0-6 : Data Sheet of Arduino Ethernet Shield

This module has been used for connect hardware unit and the web applications. The connection has been established via a WIFI router and by using an ethernet cable.

3.6 Current Sensor (ACS712)

For current measurement, current sensor ACS 712 (20 A) can be used. There are different current range ACS712 sensor available in the market, it is need to choose relevant sensor according to the requirement.

From Data Sheet

1. ACS 712 measure positive and negative 20Amps, corresponding to the analog output 100mV/A
2. No test current through the output voltage is VCC / 2 =5v/2=2.5V

Calibration:

- Analog read produces a value of 0-1023, equating to 0v to 5v
- So Analog read 1 = (5/1024) V =4.89mv
- Value = (4.89*Analog Read value)/1000 V
- But as per data sheets offset is 2.5V (When current zero will get 2.5V from the sensor's output)
- Actual value = (value-2.5) V
- Current in amp =actual value*10

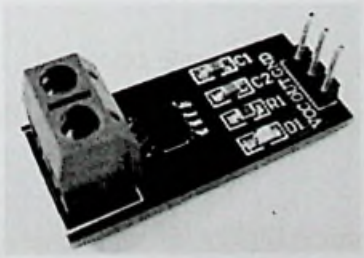

Figure 0-7: ACS712 current sensor

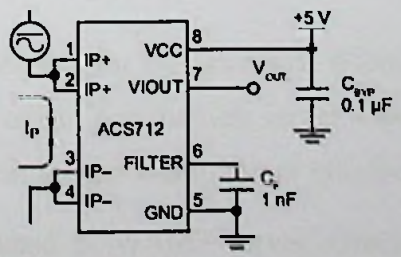

Figure 0-8: Data sheet of ACS712 current sensor

3.7 Oracle

An Oracle database is a collection of data treated as a unit. The purpose of a database is to store and retrieve related information. A database server is the key to solving the problems of information management. In general, a server reliably manages a large amount of data in a multiuser environment so that many users can concurrently access the same data. All this is accomplished while delivering high performance. A database server also prevents unauthorized access and provides efficient solutions for failure recovery.

Oracle Database is the first database designed for enterprise grid computing, the most flexible and cost effective way to manage information and applications. Enterprise grid computing creates large pools of industry-standard, modular storage and servers. With this architecture, each new system can be rapidly provisioned from the pool of components. There is no need for peak workloads, because capacity can be easily added or reallocated from the resource pools as needed. Oracle database interfaces represents in Appendix E.

The proposed system is used the Oracle database version is 11g. The database is located in a centralized server. The database has well organized tables and sequences. The hardware unit and web applications are saving and retrieving data into database and from database.

3.8 PHP

PHP (recursive acronym for PHP: Hypertext Preprocessor) is an open source general-purpose scripting language that is especially suited for web development and can be embedded into HTML.

The web applications have been developed using ATOM framework and PHP language.

3.9 Wamp Server

Wamp Server refers to a software stack for the Microsoft Windows operating system, created by Romain Bourdon and consisting of the Apache web server, OpenSSL for SSL support, MySQL database and PHP programming language. Wamp server interfaces represents in Appendix E.

Web applications have been hosted in WAMP server. Oracle database connection and web application connectivity has been established through the WAMP server.

3.10 DTM Data Generation Tool

DTM Data Generator is a software product that produces data rows and schema objects for testing purposes: test database population, performance analyzing, QA testing or loading tests fulfillment. The generator was designed to provide developers and quality assurance engineers with high quality and realistic test arrays. It automatically creates data values and optional schema objects (tables, views, procedures, triggers, etc). DTM Data Generation Tool interfaces represents in Appendix E.

This tool has been more useful to generate sample test data regarding to the analysis. New rules were created to generate those data. It was a licensed tool and I have used a free version. So, therefore there were limited features to generate data. But, it was enough for my work.

3.11 Rapid Miner Studio

Rapid Miner Studio is very useful as a classroom tool for teaching students about data analytics. Rapid Miner's workflow paradigm offers the user a very powerful analytics tool. Beginning students or students with limited computer experience may initially find the workflow paradigm difficult. Rapid Miner Studio interfaces represents in Appendix E.

The data analysis part done by using this tool. Cluster analysis techniques were used to analyze the data. And further, linear regression analysis technique was done to predict some data. Those analyzed data most useful to the managerial staff in LECO.

3.12 Summary

This chapter described the technologies were used to implement the system. We could identify the suitable technologies need to use for our implementation. Those were cost effective and more reliable technologies. Some software tools were licensed software. But there was free versions and those are having limited features. Some technologies were not suitable to implementation. Time has been spent to the research work on those technologies. But, finally I could identified the relevant, suitable and best technologies for implementation. Next chapter describes input, output, process, features and users.

Chapter 4

Smart Home Approach to Domestic Electrical Appliances

4.1 Introduction

Here we describe our novel approach to Smart Home. DOMEMS, giving the meaning that energy monitoring and control system extended. The smart home technology can be used to monitor, warn and carry out functions according to selected criteria. Smart home technology also makes the automatic communication with the surroundings possible, via the Internet, ordinary fixed telephones or mobile phones. Smart home system uses advanced computer technology, network communication technology and automatic control technology, which combines the subsystem into a control system including lighting control, temperature control, fire and burglar alarm control, main house power supply switching system.

4.2 Hypothesis

Design and implement an energy control and monitoring system to control appliances and monitor the energy consumption integrating with decision support approach.

4.3 Users

The number of uses can be benefited by the DOMEMS systems in multiple ways. More importantly, LECO and CEB (Ceylon Electricity Board) and their consumers and university students can be directly benefited by this solution. Those who are interested in study of energy control and monitoring can also use this system for learning purposes. Two types of users are interacting with the system as,

- LECO staff- there is an administrative web application and analyzed data for advanced decision support.
- LECO consumers – there is a customer web portal to control and monitor the customer' electrical appliances.

4.4 Input

The system can accept from various devices including a computer connected to the Internet, Smart devices.

The web applications' input could be as,

- Username, password (authentication keys), security code
- Appliances details (capacity, type, brand, lifetime, etc)
- Customer details (electricity account no, name, location, contact no)
- Push ON/OFF button
- Choose menu item

The hardware units' input as,

- Appliances' Ampere
- Appliances' Watt

Any user accessing the system should go through an authentication process.

4.5 Output

Web applications output as below.

- Notifications (appliance ON or OFF, etc)
- Statistical details / graphs
- Special news from Electricity Company
- Summarized electricity consumption units in previous few months ago

Hardware units' output as below.

- Appliances' consumption
- Consumption period
- Appliances ON/OFF status

Special information from LECO will be notified on the customer web portal to display to the consumers.

4.6 Process

The system executes a user authentication process before allowing a person to use the facilities of the system. This process goes beyond verification of user name and the password, but asks for

security given the user when login into the system in every time. There is a dual authentication process in this system due to security purpose. All the consumers need to use their electricity account no as username. Then they will receive a security code to the mobile which needed to use as security code enter to the system. LECO staff web portal is vary than the customer portal. They needed to use their employee no (Ex: A-180) as username and password which they were created. Having permitted the user access the system offers facilities to select item from the menu list.

LECO consumer ability to,

- Logging into the system
- Select the menu
- Ability to add appliances
- Ability to check electricity consumption on the current day
- Select the relevant appliance
- Turn ON/OFF the appliance using push button
- Check the previous month's consumption, check the statistics
- Ability to see special notices from LECO
- Logout

LECO staff ability to,

- Logging into the system
- Ability to get statistical and analytical data, consumer wise electricity consumption, monthly wise electricity consumption, peek/off-peek wise electricity consumption
- Logout

The hardware unit will plug into the consumers' home. The unit will transmit the consumption of appliances into the database. The appliances ability to control through the customer web portal by using hardware unit.

Further, all data is represented as statistical data in Google charts on web portals. And advanced analysis can be done by using any data mining tool such as Rapid miner. Those analyzed data will useful to the managerial staff in LECO.

4.7 Features

In connection with the input, output, users and process, the over features of the system include the following characteristics.

- Reduced Installation costs – low cost and high accuracy featured components are integrated.
- Internet Connectivity – LECO areas are not located in rural. Most of the customers are nearby main cities. Internet coverage is trusted in those areas.
- Scalable and Expandable – hardware unit can be expandable by using advanced components and new sensors.
- Security - enabled confidentiality authentication process.
- User friendly – ability to understand the details on web application and ability to use easily.
- Accuracy – information of the system saving into database in every moment. No data losses.

4.8 Summary

This chapter described the approach of DOMEMS. We identified the users, features of the DOMEMS, input and outputs and finally completed with the process. Next chapter describes design of the DOMEMS.

Chapter 5

Design of DOMEMS

5.1 Introduction

The previous chapter gave full picture of the entire solution. This chapter describes the design of solution for the process presented in the approach. DOMEMS design the solution as a client-server system with a backend database. Here we describe the top-level architecture of the design by elaborating on the role of each component of the architecture. Generally this research is divided into two main tasks, namely controlling devices and providing current information. The controlling and providing information task are conducted by combines the Arduino microcontroller which connected to a router in the house and can be accessed by smartphone using WIFI and Bluetooth.

5.2 Top level architecture of DOMEMS

The top-level architecture of DOMEMS comprises of three main modules namely, client, server and appliances control modules. Figure5.1, illustrates the Top Level architecture.

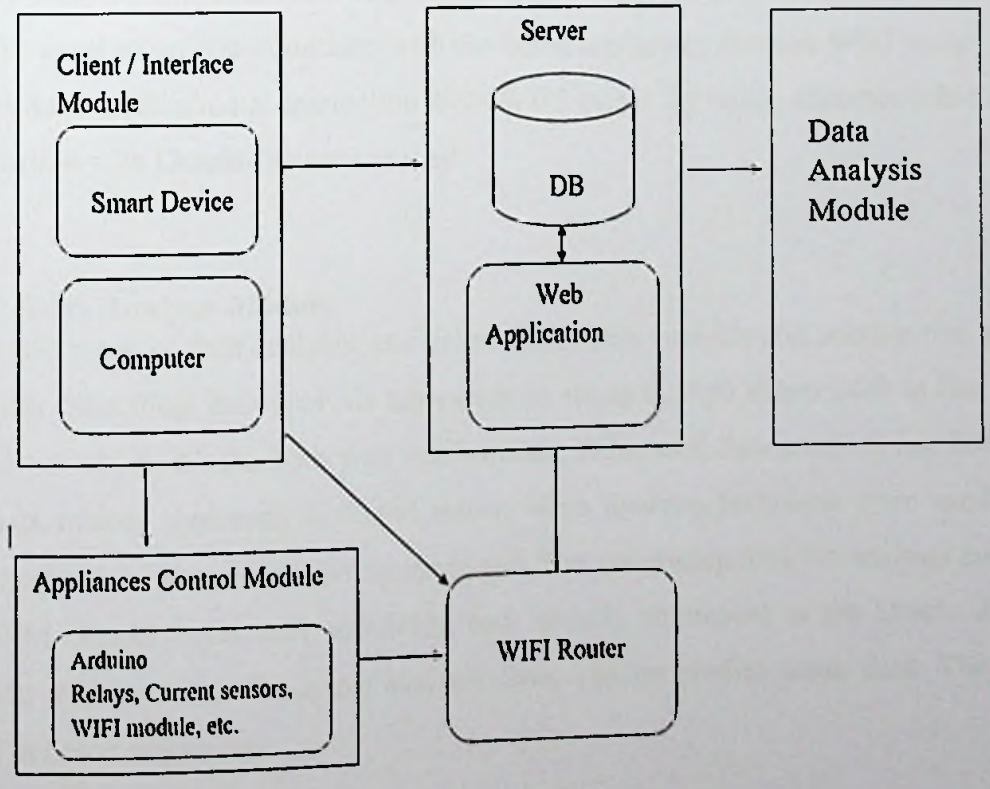

Figure 0-1: high level architecture

5.3 Interface/ Client Module

This module consists of two sub modules are smart devices and computers. Those sub modules give access to the system. It enables interacting with the system through a desktop client for web application and a smart device for web application. Through these sub modules user authentication, secure login, etc. are provided. The interface module offers facilities for entering inputs and also receiving multiple forms of output information. This module comes as a part of client side software of the solution. The smart phone is provided with web app to access the overall solution.

5.4 Server Module

The sever works as the central point of the system. All services provided by the solution must be accessed through the server. The server has connection to the backend database and the web based application. The server has installed a PHP server is WAMP server and web applications hosted on this server. A database has installed in the server is Oracle.

5.5 WIFI Router

The server module, Client module and Appliances control module are connected to the WIFI router. Web application communicates with the home appliances through WIFI router. Appliance control module established a connection with WIFI router by using Ethernet cable to enabled communication with Oracle database as well.

5.6 Data Analysis Module

There are two types of data analysis, one is statistical data analysis and another one is advanced data analysis. Statistical data analysis represents by using Google charts such as line charts, pie charts and bar charts on the both web applications. Advanced data analysis has been done by using a data mining tool such as Rapid miner. Main analysis technique were used is Cluster analysis. Some data were generated by using test data generating tool for analysis purpose. The tool is DTM. Rapid miner tool and DTM tool directly connected to the Oracle database by establishing a connection. By using analysis data, can be predict some data. The prediction technique is linear regression.

5.7 Appliances Control Module

The module is a unit of hardware. Arduino UNO microprocessor, current sensors, WIFI modules, Ethernet shield, Relay modules are connected together. The hardware unit programmed by using Arduino IDE and program uploads into microprocessor. Ethernet shield, relay modules and current sensors are connected into the microprocessor and those modules will receive signals via the microprocessor. The unit sends the digital signals to the appliances to control them and get information from them.

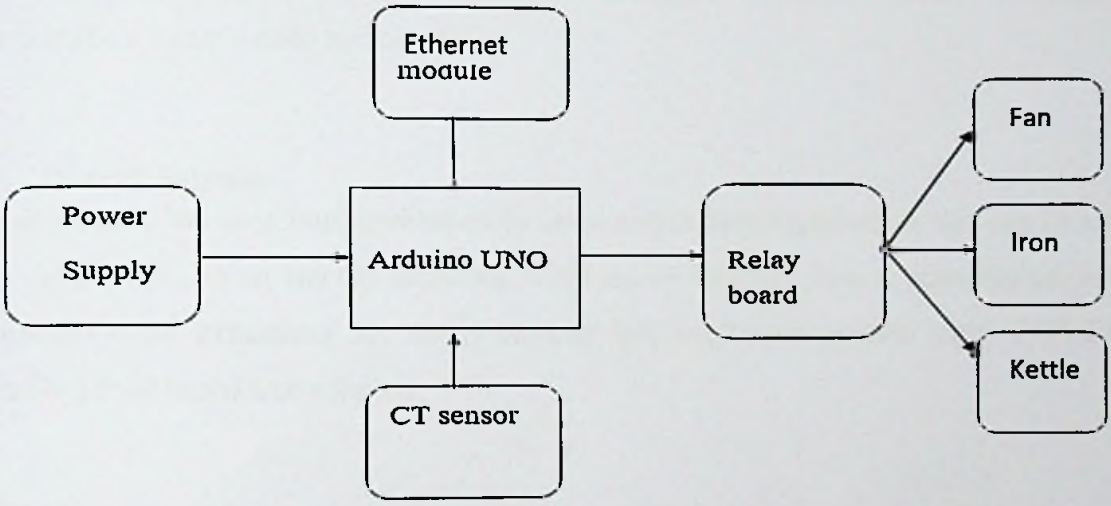

Figure 0-2: Appliances Control Module

5.8 Summary

This chapter represented the system design and module, sub-modules design using diagrams. The high level architecture includes and all the modules and sub modules described in this chapter. Next chapter describes the implementation of DOMEMS.

Chapter 6

Implementation of DOMEMS

6.1 Introduction

There are several platforms for developing smart phone applications such as Windows Mobile, Symbian, iOS and Android. In the proposed system, the web application is developed as most of the phones and handy devices support web apps. PHP language using the Atom IDE has been used for the development and implementation of the smart home app. The Atom IDE includes a complete set of development tools such as debugger, libraries, handset emulator with documentation, sample code and tutorials.

6.2 Overall Solution

Overall solution has been implemented as an Open source based application that can be accessed by any client running on any OS including Windows or Android. This is primarily client-server architecture with extensions for smart devices and appliances control unit. DOMEMS is primarily a PHP based web solution.

6.3 Implementation of the Interface/Client Module

The interface module has been designed to validate user authentication, password login etc. And even, this module has been implemented a dual authentication process to the customer portal to increase the security. When a customer needs to login into his web portal, a SMS with including a security code will be received to his mobile phone and his needs to enter the code correctly to enter into the system. This module has two sub modules. The computer based application is located within the server and it has developed using PHP and using Atom framework. Data has been retrieve, save and update through PHP and Oracle database connection. The consumer ability to control their home appliances in remotely by using customer portal. And they can compare their home electricity consumption and bill amounts with previous months as well. The client need to get the application from LECO web site and have install into the device. The administrative portal shows the statistics as customer wise, CSC wise and ability to get overall conclusion about the sale of branch as a support of decision making. As well as, it is available to send bulk notifications through the web application to the LECO consumers. The web

application insert the notification and consumers' account numbers into the LECO SMS engine. Then consumer will notify in two ways, one is through the customer portal and another is mobile SMS. Appendix A shows a prototype of the main Interfaces in the system. This shows wide range of input and output facilities offered by the DOMEMS.

6.4 Implementation of Server Module

The server has been implemented to run on Linux or Windows operating system. The server uses the Apache web server for all communication. The PHP server is WAMP server. The server has been located at LECO. The database is Oracle 11g. Table 6.1 shows the server hardware configuration details.

Processor	1.65 GHz
Memory	4GB RAM
Hard Drive Storage	40 GB
Operating System	Windows / Linux
Additional Software	PHP • Wamp Server Oracle • Version 11g • Oracle thin client

Table 6-1: Server configuration

The Figure 6.2 represents the flow diagram of the process between server and web application.

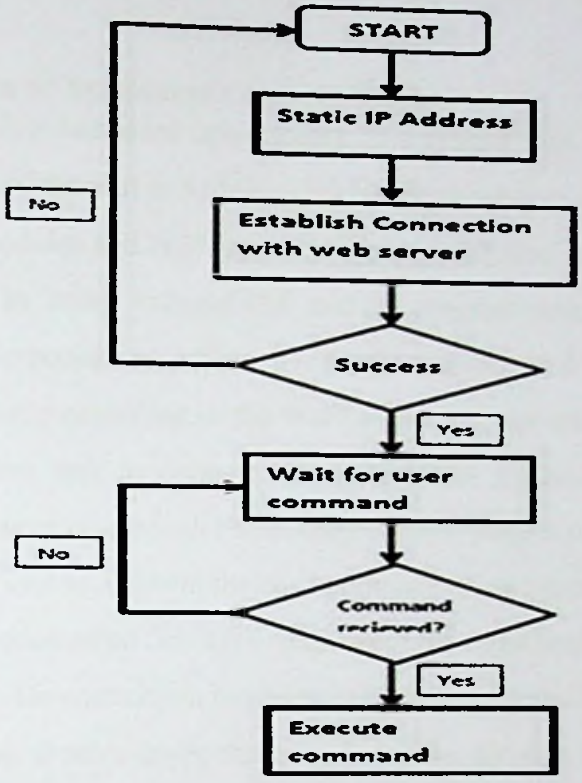

Figure 0-1: flow diagram of the process between server and web application

6.5 Implementation of Data Analysis Module

Statistical analysis has been implemented using Google charts on web applications. Customer portal has been implemented to represent the current month consumption, bill amount, previous few months' consumption, bill amounts, average consumption in charts. Further, the administrative portal has been implemented the Google charts to represent CSC wise consumption, customer wise consumption and those consumption in current month and previous month. Appendix A represents the charts included interfaces. LECO managerial staff needs the advanced analyzed data to decision making process. The advanced analysis process has been implemented using data mining tool such as Rapid miner. There are more data mining techniques to analyze data. I have implemented cluster analysis technique to analyze data. Some data has been generated using test data generation tool for analysis purpose. And further, it has been implemented a prediction model to predict some data according to the requirement. The prediction technique is linear regression technique. It has been implemented by using few data set. Appendix A represents the analysis results and other interfaces on regarding to this.

6.6 Implementation of Appliances Control Module

This module includes few hardware components. The control unit developed integrating these components. The heart of the unit is Arduino UNO microprocessor. An Ethernet shield, ACS712 current sensor, relay modules and WIFI router has been integrated into this unit. Microprocessor has been programmed by using Arduino IDE and the program tested through this IDE. All the modules' commands, responds and actions have been implemented with this program. Ethernet shield has been configured according to the WIFI router settings and server IPs. Relay modules has been integrated into unit to connect electrical home appliances and with enabling the commands by web application through the microprocessor program. ACS712 current sensor has been implemented into unit to measure the consumption of home appliances. The microprocessor program has been implemented to store the electricity consumption into Oracle database. Therefore, Oracle database connection has been implemented with this microprocessor program. Any data is not required to store inside the unit. Therefore, the unit has not integrated a SD card or any other such component. If there is an electricity failure, it will not be harmful to the device or even to the system. At the moment, the database has the last consumption value stored. And even, it is not required to store Date Time inside the unit. The Date and Time is pick-up from the server when it is connected into the server. Appendix A represents the unit and the components.

6.7 Summary

This chapter described the implementation of DOMEMS. Main modules were described in this chapter are Client module, Server module, Appliances control module and Data analysis module. Those modules has been implemented using previously described technologies. Next chapter describes the evaluation of DOMEMS.

Chapter 7

Evaluation of DOMEMS

7.1 Introduction

This chapter discuss the evaluation of the new approach by assessing of meeting the objectives. In particular, we evaluate the prototype to analyze whether the hypothesis can be substantiated. Here we discuss the kind of participants, test cases (questions being asked), data collections, data analysis and presentation of the results.

7.2 Participants

The major participants in this research are LECO consumers in the Kotte branch. The data has been collected based on this branch.

7.3 Test cases

The test cases represents in Appendix – D.

7.4 Data collection

Major data surveys are collected from LECO database with the help of LECO IT staff. The data existing from October, November and December, 2016. The data has been inserted into the database tables with avoiding unnecessary information. The rest of the data has been completed based on those data. The rest of data are generated using a test data generation tool. But the monthly energy consumption units are the real data in this data set. And further, peek and off-peek consumption units are the real data. No of appliances, appliances' capacity, purchased date and utilized time are the randomly generated data by using test data generation tool. The data has been organized in the Oracle database and into separate tables. All the tables are having well prepared data for the data analysis.

7.5 Data analysis

The analysis of the survey data is processed using Oracle database and integrating with an analyzing tool to analyze it. The statistical analyses that have been conducted include: overall multi-dimension constructs measurement towards each factor, descriptive statistics, regression

statistics, non-parametric and parametric tests. The chosen analysis theorem is cluster analysis. Clustering finds group of data which are somehow equal. For this analysis, K- means algorithm was used. The algorithm searches for the k groups, which have the smallest average distance to the cluster centroid (=the smallest in-cluster variance). And other analysis were represented using Google charts such as pie charts, line charts and bar charts. There are many data mining techniques to analyze data. Figure 7-1 represents the available data mining techniques.

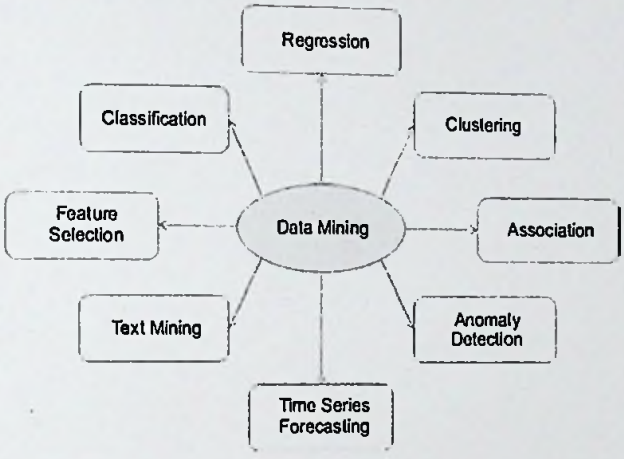

Figure 0-1 - Data mining techniques

Tasks	Description	Algorithms	Examples
Classification	Predict if a data point belongs to one of the predefined classes. The prediction will be based on learning from a known data set.	Decision trees, neural networks, Bayesian models, induction rules, k-nearest neighbors	Assigning voters into known buckets by political parties, e.g., soccer moms Bucketing new customers into one of the known customer groups
Regression	Predict the numeric target label of a data point. The prediction will be based on learning from a known data set.	Linear regression, logistic regression	Predicting unemployment rate for next year Estimating insurance premium
Anomaly detection	Predict if a data point is an outlier compared to other data points in the data set.	Distance based, density based, local outlier factor (LOF)	Fraud transaction detection in credit cards Network intrusion detection
Time series	Predict the value of the target variable for a future time frame based on historical values.	Exponential smoothing, autoregressive integrated moving average (ARIMA), regression	Sales forecasting, production forecasting, virtually any growth phenomenon that needs to be extrapolated
Clustering	Identify natural clusters within the data set based on inherit properties within the data set.	k-means, density-based clustering (e.g., density-based spatial clustering of applications with noise [DBSCAN])	Finding customer segments in a company based on transaction, web, and customer call data
Association analysis	Identify relationships within an item set based on transaction data.	Frequent Pattern Growth (FP-Growth) algorithm, Apriori algorithm	Find cross-selling opportunities for a retailer based on transaction purchase history

Table 7-1-Comparison of Data Mining Techniques

Table 7-1 represents the comparison of data mining techniques. According to this study I have been selected cluster analysis and regression technique to analyze the data. Appendix G represents all the analysis results with screen shots.

7.6 Summary

This chapter described evaluation of DOMEMS. Next chapter describes conclusion of this research.

Chapter 8

Conclusion and Future Work

8.1 Introduction

Previous chapter contained the evaluation details about the Energy Monitoring and Decision Support System. This chapter represents the overall achievement of this research, limitations and future works.

8.2 Achievement

The main motivation behind this work of a Smart Home Technology and Data Mining is to achieve a higher energy efficiency, to maximize the utilization of electricity efficiency domestic appliances, to minimize the inquiries of consumers due to blind energy consumption of energy meters. The primary objective of the project was achieved. This research doesn't only focus only on the theoretical aspects of the DOMEMS but it did yield concrete hardware prototypes.

The first part of the project consisted of monitoring and control of appliances in a Home Energy Monitoring System. The first phase was the collection of data from LECO. Then, insert those data into the database and organize them. Then, based on this organized data generate the transaction data using test data generation tool. After that, make sure that relevant the generated data according to the collected consumers' data. The last phase, data must be compatible with original data.

The second step of this project was the analysis of the possibility of perform the efficiency of domestic appliances and control the appliances using the system in our home energy system. In this step, a hardware unit was made with capability of plug the selected electricity appliances. After doing some testing, we could conclude that hardware unit is still difficult to implement completely in houses because of some enhancements needed to be done.

The last part merged the work done (monitoring and control) with the web application development done which gave a strong aspect to the project. It has two main parts such as, Admin web portal and Customer portal. Admin web portal includes, all the consumers' energy consumption as statistical data. In this project, has represented the data only relevant to the LECO Kotte branch and three months consumption only. Customer portal includes, the energy

consumption patterns of their home according to their home appliances and could control the connected appliances such as ON/OFF. They can see their energy consumption comparing three months in each time and can be identify the appliances which need to be replaced due to high energy consumption. Further, they can see their current consumption unit and they can do the necessary things according to the current consumption. And finally, consumer receives special notices from LECO via the customer portal.

Finally, this research identified some energy consumption patterns in domestic appliances that help for decision making for energy management. That include consumer wise changes, customer service centers wise changes as well as branch wise changes can be identified. Use of these patterns LECO management can make effective decisions for energy sales, efficiency electricity distribution and well customer service, etc.

8.3 Limitations and Further work

This research is mainly focuses to decision making solution to LECO and their consumers. Therefore, this research tries to gather electricity consumption units of all the home appliances day by day in hourly. However present company gather the electricity consumption monthly and it is a whole consumption units during the month.

The limitations on the project could be stated as follow: first the high cost of the system implementation among LECO consumers. Second, the lack of knowledge of some consumers and disfavor to accept new hardware and software unit. Another thing is lack of internet facility among all consumers.

In the context of the DOMEMS, a number of future projects could be undertaken to complete and enhance this project: The implementation of the sensing network using both a voltage sensor and a current sensor along with adding sensors such as gas, motion, humidity sensors, etc. Second, enhancing privacy and security of the data communicated within the system. Third, enhancing the system's intelligence by using optimization algorithms.

Increasing accuracy of this research future researches may design and implement an architectural framework for a web based demand management system that allows an electric utility to reduce system peak load by automatically managing end-use appliances based on consumers'

preferences. As well as researchers may find out more electricity consumption patterns that helps to decision making to the management of electricity industry.

8.4 Summary

This chapter describes the overall achievement of this research as well as this chapter represents limitations and future works on regarding the research.

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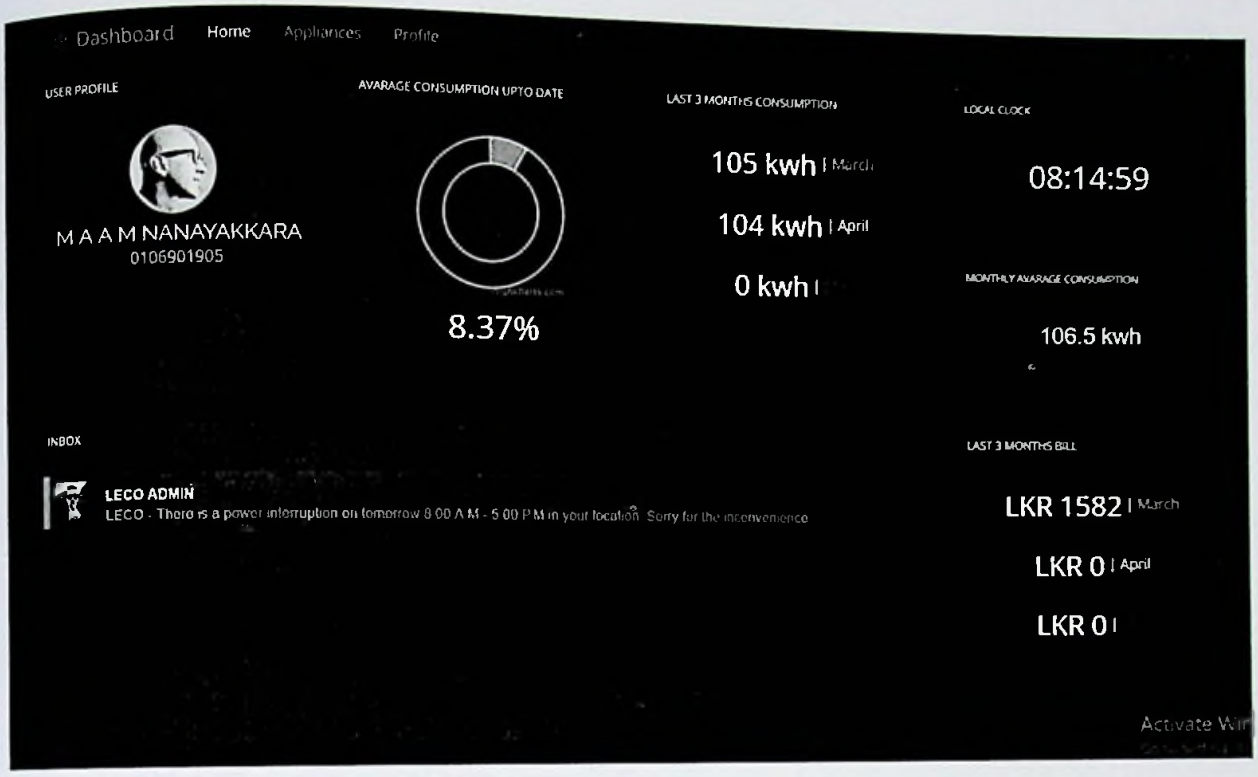
Appendix A- Images explaining the Graphical User Interface of DOMEMS

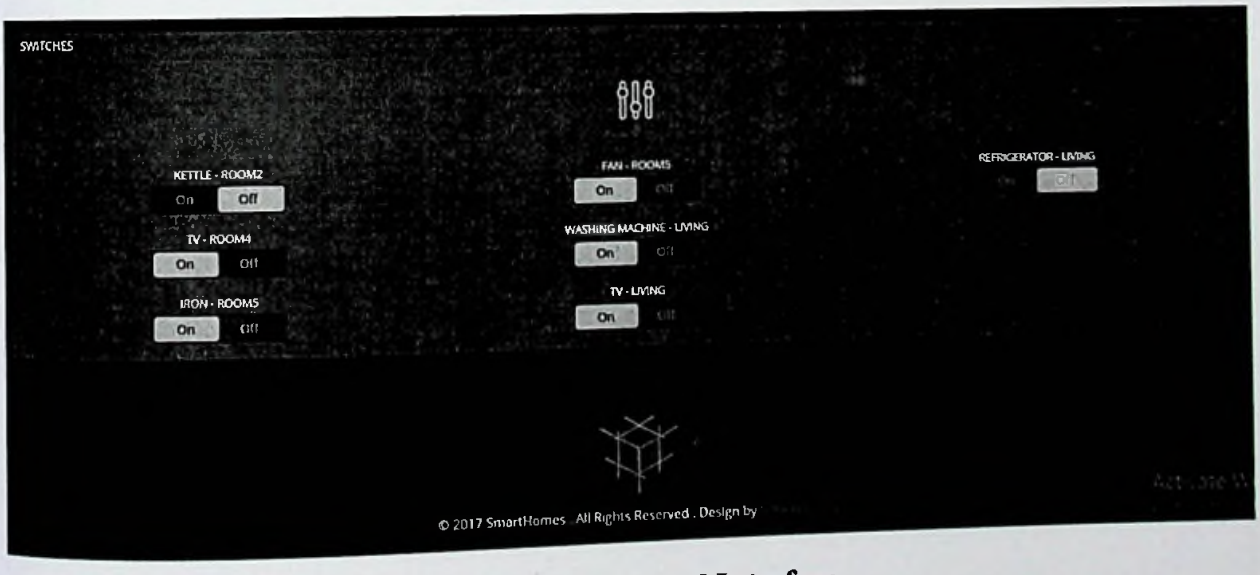
GUI screenshots of customer portal

http://localhost/smarthome

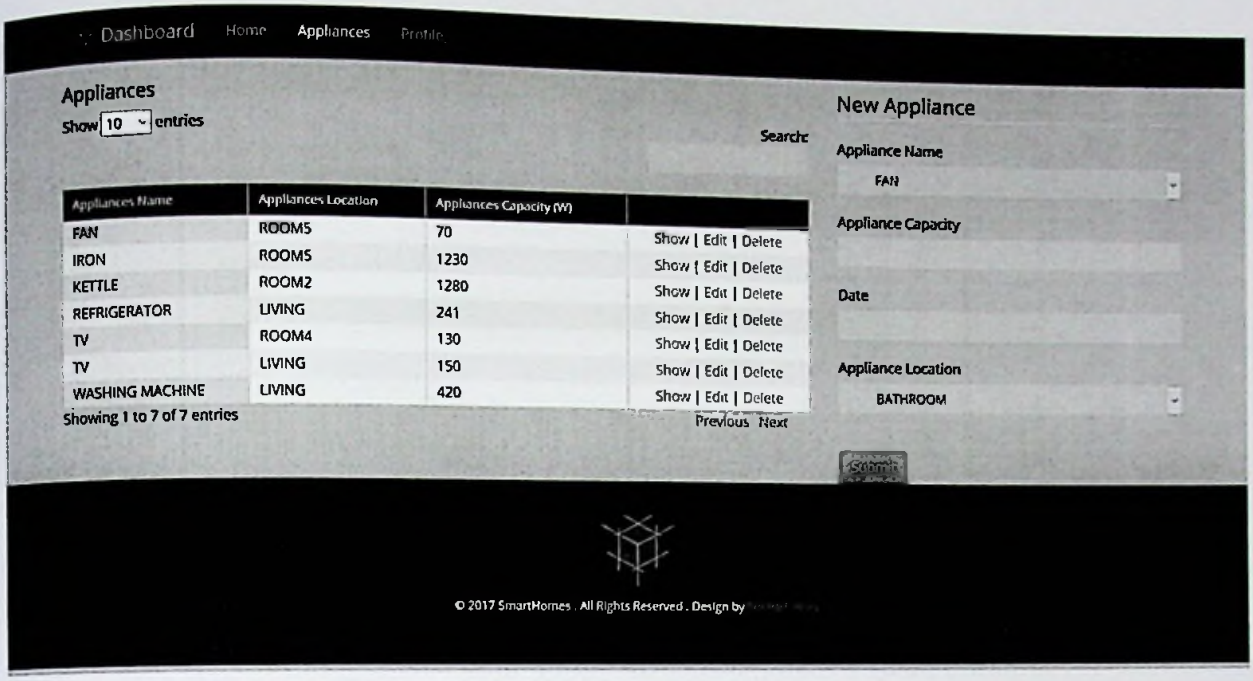
User Login Screen



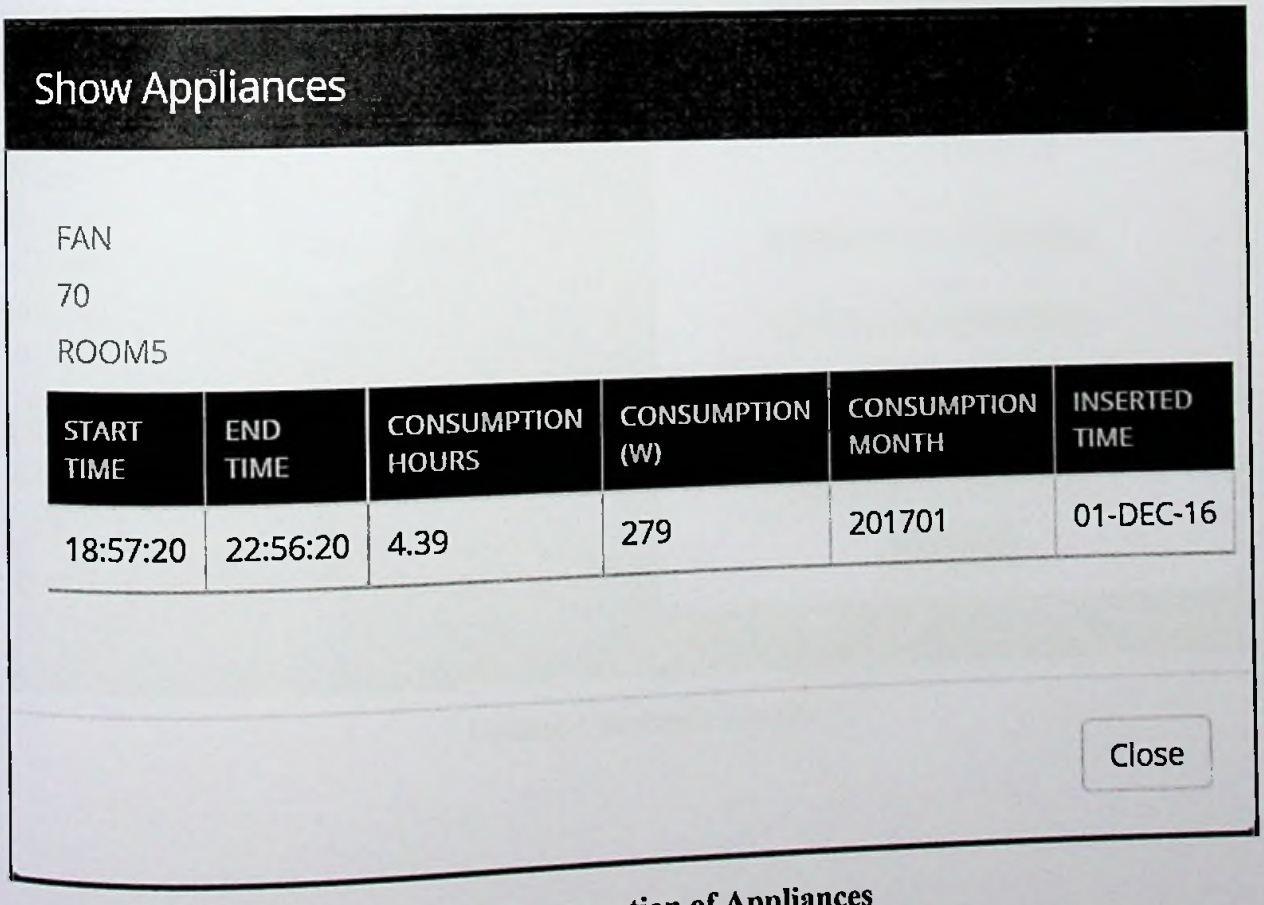
Home Page



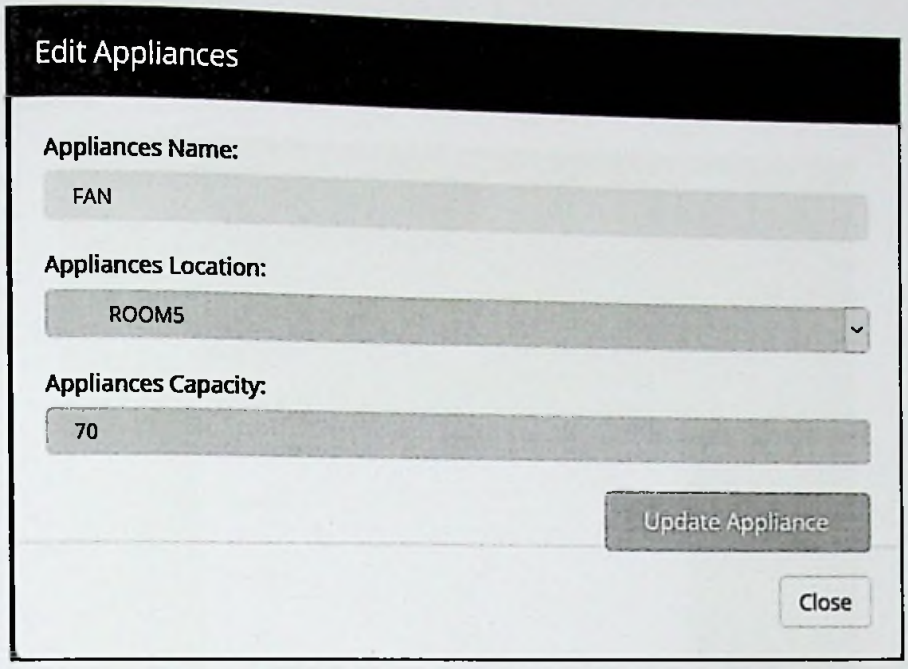
Appliances Control Interface



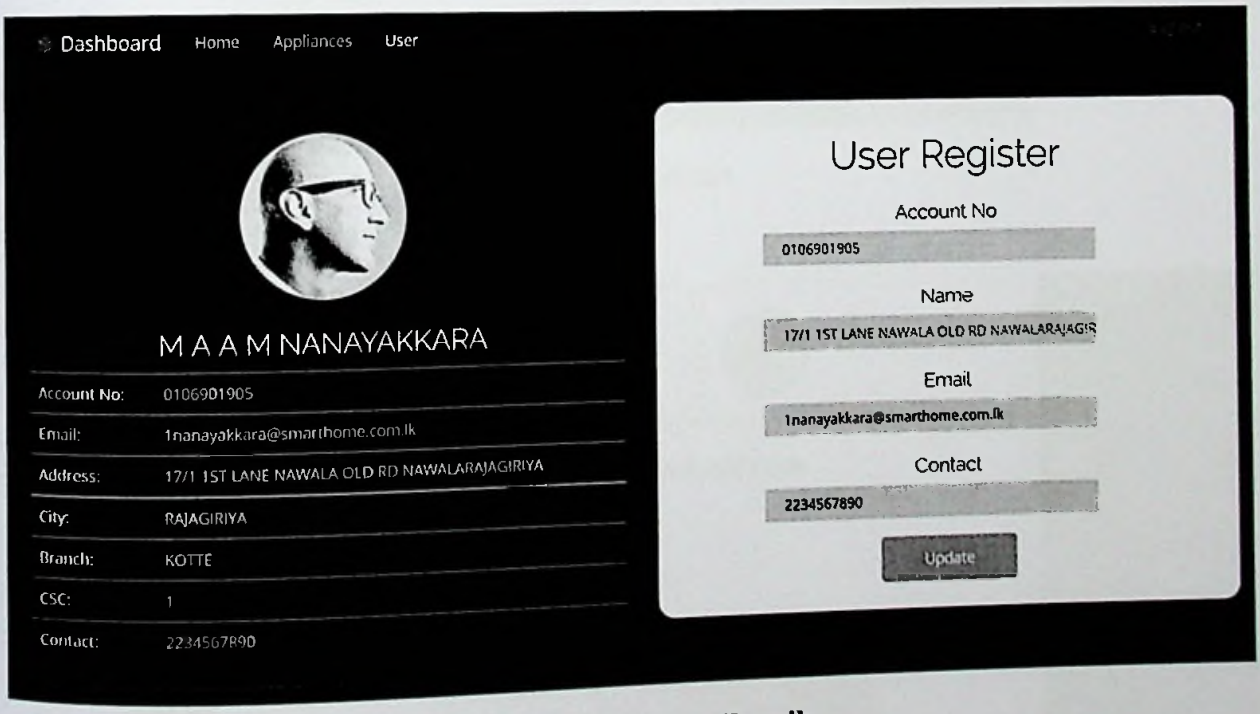
Add New Appliance



Show Consumption of Appliances



Edit Appliances Details

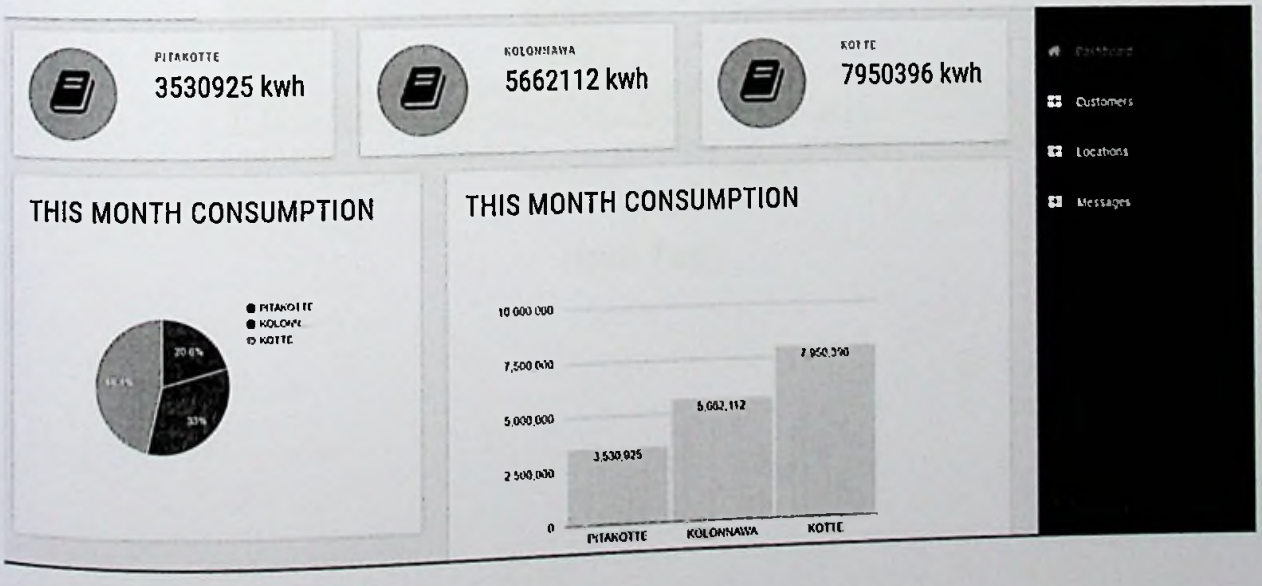


Update Consumer Details

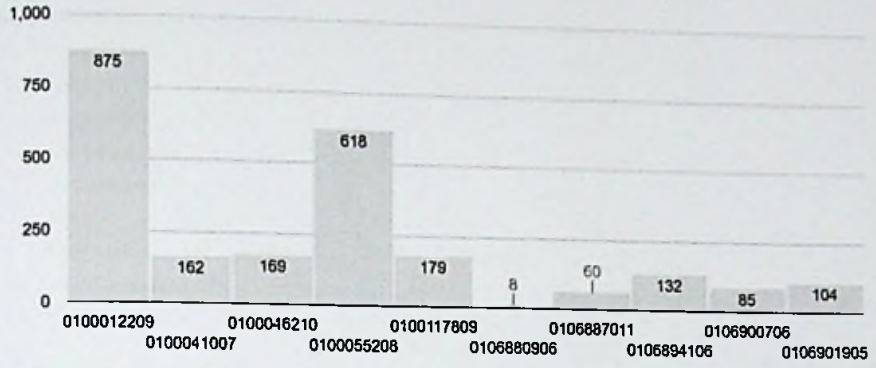
GUI screenshots of administrator portal

http://localhost/web/

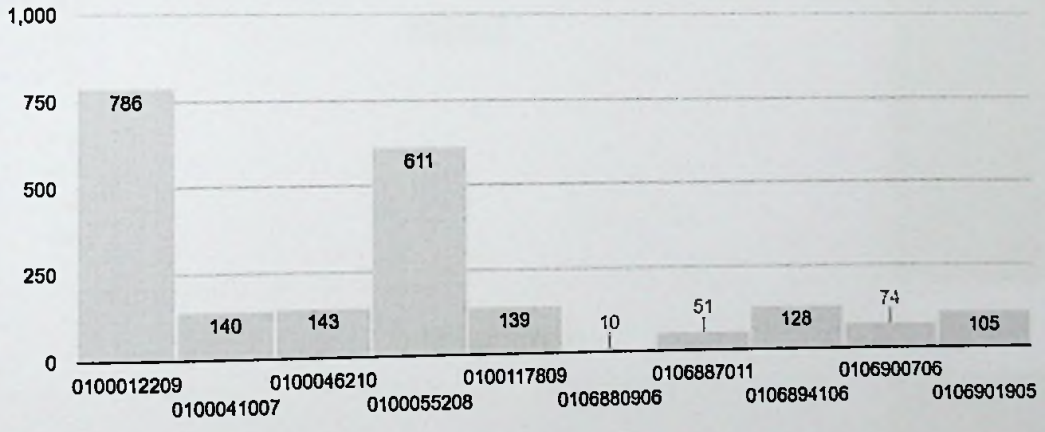
Login Admin



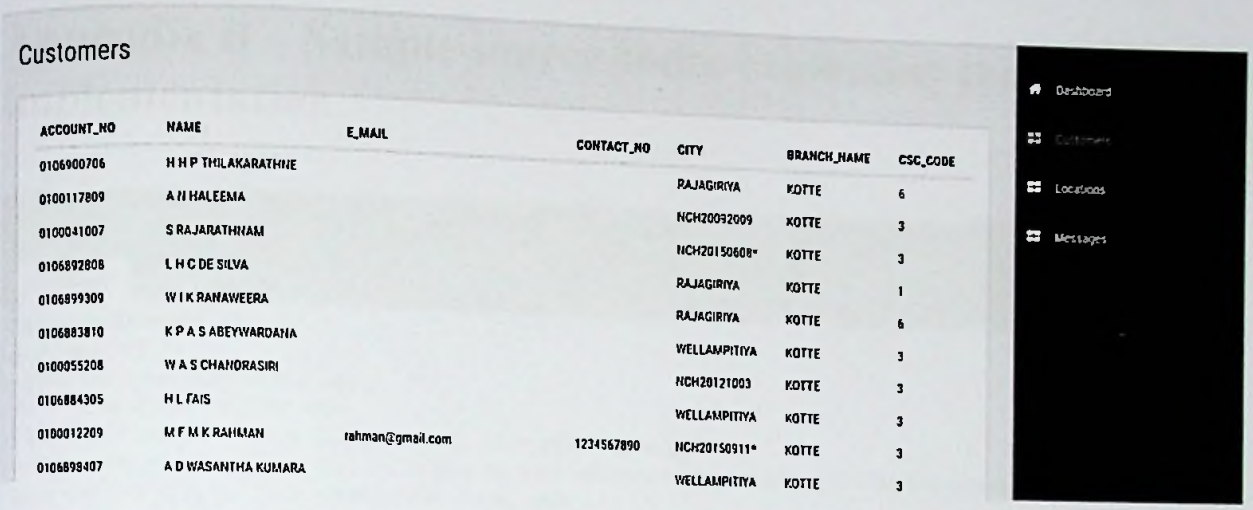
THIS MONTH CONSUMPTION (CUSTOMER WISE)



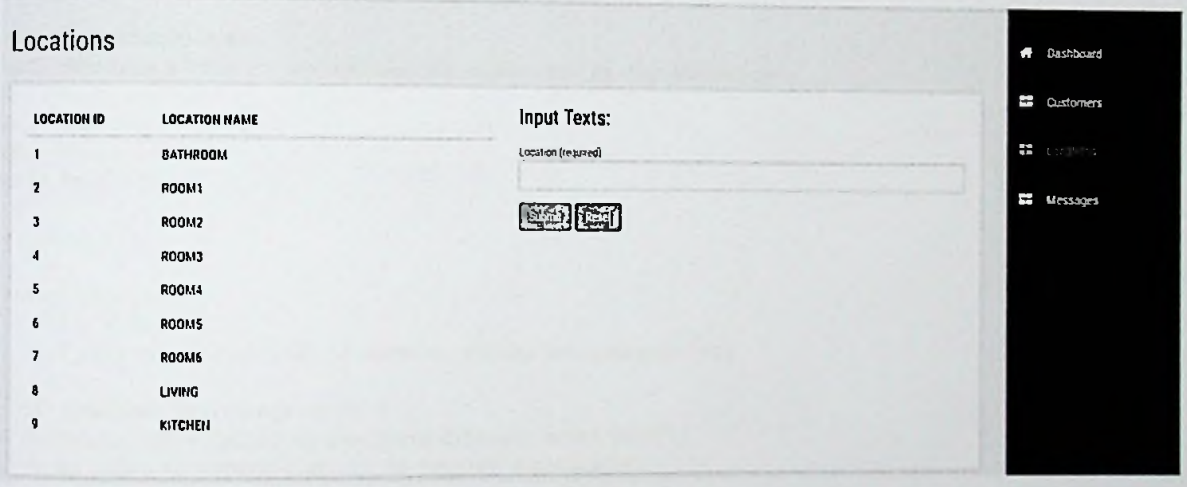
LAST MONTH CONSUMPTION (CUSTOMER WISE)



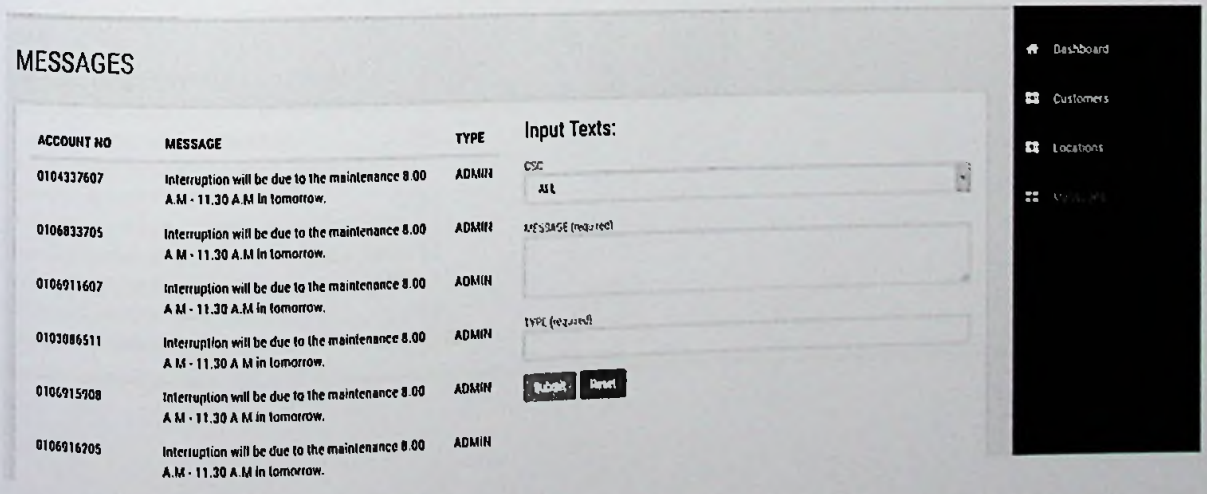
Home Page



Customers GUI



Add Locations



Send Bulk Notifications

Appendix B – Sample source codes explaining the implementation

datasave

```
#include<Ethernet.h>
#include<SPI.h>
const int temperaturePin = A0;
// **** ETHERNET SETTING ****
// Arduino Uno pins: 10 = CS, 11 = MOSI, 12 = MISO, 13 = SCK
// Ethernet MAC address - must be unique on your network - MAC Reads T4A001 in hex (unique in your network)
byte mac[] = { 0x90, 0xA2, 0xDA, 0x0F, 0x3A, 0xDC };
// For the rest we use DHCP (IP address and such)
IPAddress ip(192,168,8,103);
EthernetClient client;
IPAddress server(192,168,8,1); // IP Adres (or name) of server to dump data to
int  interval = 5000; // Wait between dumps

const int analogIn = A0;
double mVperAmp = 185; // use 100 for 20A Module and 66 for 30A Module
double RawValue= 0;
double ACSoffset = 2500;
double Voltage = 0;
double Amps = 0;

void setup() {

  Serial.begin(9600);
     while (!Serial) {
    ; // wait for serial port to connect. Needed for Leonardo only
  }
    if (Ethernet.begin(mac) == 0) {
    Serial.println("Failed to configure Ethernet using DHCP");
    // no point in carrying on, so do nothing forevermore:
    // try to congifure using IP address instead of DHCP:
    Ethernet.begin(mac, ip);
  }


  Serial.println("");
  Serial.println("-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-\n");
  Serial.print("IP Address        : ");
  Serial.println(Ethernet.localIP());
  Serial.print("Subnet Mask       : ");
  Serial.println(Ethernet.subnetMask());
  Serial.print("Default Gateway IP: ");
  Serial.println(Ethernet.gatewayIP());
  Serial.print("DNS Server IP     : ");
  Serial.println(Ethernet.dnsServerIP());
```

```
void loop() {
  // if you get a connection, report back via serial:
  if (client.connect(server, 80)) {
      float tem = getTemp();
    Serial.println( tem );
    Serial.println("-> Connected");
    if(client.connected()){
    // Make a HTTP request:
    client.print( "POST /smarthome/write_data.php");
    Serial.println("-> Connected11111");
    //client.print("serial=");
    //client.print( "CurrentSensor" );
    //client.print("&&");
    //client.print("consumption=");
    //client.print( tem);
    client.println( " HTTP/1.1");
    client.println( "Host: 127.0.0.1" );
    //client.println(server);
    client.println( "Connection: close" );
    client.println();
    client.println();
    client.stop();
  }
  }
  else {
    // you didn't get a connection to the server:
    Serial.println("--> connection failed/n");
  }

  delay(interval);
}
float getTemp() {
  RawValue = analogRead(analogIn);
 Voltage = (RawValue / 1024.0) * 5000; // Gets you mV
 Amps = ((Voltage - ACSoffset) / mVperAmp);

 Serial.print("Amps = "); // shows the voltage measured
 Serial.println(Amps,2); // the '2' after voltage allows you to display 2 digits after decimal point
 delay(1000);
  return Amps;
}
```

Source Code of microprocessor program

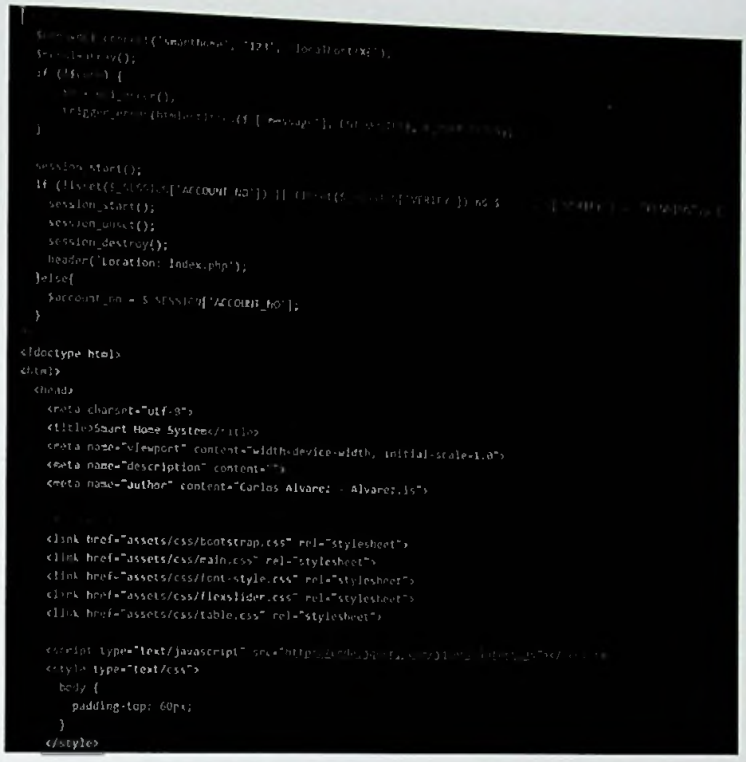
Index.php

index.php

```
<!doctype html>
<
$conn=oci_connect('smarthome', '123', 'localhost/XE');
if (!$conn) {
    $e = oci_error();
    trigger_error(htmlentities($e['message'], ENT_QUOTES), E_USER_ERROR);
}
session_start();
if (isset($_SESSION['ACCOUNT_NO'])) {
  header('Location: dashboard.php');
}
?>
<html>
  <head>
    <meta charset="utf-8">
    <title>Smart Home</title>
    <meta name="viewport" content="width=device-width, initial-scale=1.0">
    <meta name="description" content="">
    <meta name="author" content="Carlos Alvarez - Alvarez.is">

    <!-- Le styles -->
    <link href="assets/css/bootstrap.css" rel="stylesheet">
    <link href="assets/css/login.css" rel="stylesheet">
    <script type="text/javascript" src="http://code.jquery.com/jquery-latest.js"></script>

    <style type="text/css">
      body {
        padding-top: 30px;
      }
    </style>

    <!-- HTML5 shim, for IE6-8 support of HTML5 elements -->
    <!--[if lt IE 9]>
      <script src="http://html5shim.googlecode.com/svn/trunk/html5.js"></script>
    <![endif]-->

    <!-- Le fav and touch icons -->
    <link rel="shortcut icon" href="assets/ico/favicon.ico">
    <link rel="apple-touch-icon-precomposed" sizes="144x144" href="assets/ico/apple-touch-icon-144-precomposed.png">
    <link rel="apple-touch-icon-precomposed" sizes="114x114" href="assets/ico/apple-touch-icon-114-precomposed.png">
    <link rel="apple-touch-icon-precomposed" sizes="72x72" href="assets/ico/apple-touch-icon-72-precomposed.png">
    <link rel="apple-touch-icon-precomposed" href="assets/ico/apple-touch-icon-57-precomposed.png">
```

Source Code of Login Page

Appliances.php



```
<?php
  $conn = mysqli_connect('smarthome', '123', 'localhost');
  $result = array();
  if (!$conn) {
      $result['error'] = mysqli_error();
      trigger_error($result['error']['message'], E_USER_ERROR);
  }

  session_start();
  if (!isset($_SESSION['ACCOUNT_NO']) || !isset($_SESSION['STRIFE']) && $
    session_start();
    session_unset();
    session_destroy();
    header('Location: index.php');
  }else{
    $account_no = $_SESSION['ACCOUNT_NO'];
  }
?>
<!doctype html>
<html>
  <head>
    <meta charset="utf-8">
    <title>Smart Home System</title>
    <meta name="viewport" content="width=device-width, initial-scale=1.0">
    <meta name="description" content="">
    <meta name="Author" content="Carlos Alvarez - Alvarez.is">

    <link href="assets/css/bootstrap.css" rel="stylesheet">
    <link href="assets/css/main.css" rel="stylesheet">
    <link href="assets/css/font-style.css" rel="stylesheet">
    <link href="assets/css/flexslider.css" rel="stylesheet">
    <link href="assets/css/table.css" rel="stylesheet">

    <script type="text/javascript" src="https://code.jquery.com/jquery-1.10.2.min.js"></script>
    <style type="text/css">
      body {
        padding-top: 60px;
      }
    </style>
```

```
<link rel="shortcut icon" href="assets/ico/favicon.ico">
<link rel="apple-touch-icon-precomposed" sizes="144x144" href="assets/ico/apple-touch-icon-144-precomposed.png">
<link rel="apple-touch-icon-precomposed" sizes="114x114" href="assets/ico/apple-touch-icon-114-precomposed.png">
<link rel="apple-touch-icon-precomposed" sizes="72x72" href="assets/ico/apple-touch-icon-72-precomposed.png">
<link rel="apple-touch-icon-precomposed" href="assets/ico/apple-touch-icon-57-precomposed.png">


<link href="http://fonts.googleapis.com/css?family=Raleway:400,300" rel="stylesheet" type="text/css">
<link href="http://fonts.googleapis.com/css?family=Oxygen" rel="stylesheet" type="text/css">
<link rel="stylesheet" href="//code.jquery.com/ui/1.12.1/themes/base/jquery-ui.css">


<script type="text/javascript" src="assets/js/datatables/jquery.dataTables.js"></script>
<script src="https://code.jquery.com/ui/1.12.1/jquery-ui.js"></script>

<script type="text/javascript" charset="utf-8">
  $(document).ready(function() {
    $('#dt1').dataTable();
    $( "#datepicker" ).datepicker();
  });

  $(document).ready(function () {
    $("#btn-blog-next").click(function () {
      $('#blogCarousel').carousel('next')
    });
    $("#btn-blog-prev").click(function () {
      $('#blogCarousel').carousel('prev')
    });

    $("#btn-client-next").click(function () {
      $('#clientCarousel').carousel('next')
    });
    $("#btn-client-prev").click(function () {
      $('#clientCarousel').carousel('prev')
    });
  });

  $(function () {
    $('[data-toggle="tooltip"]').tooltip()
    $('#myCarousel').carousel({
      interval: 5000
    });
```

Source Code of Appliances Page

Dashboard.php

```
<?php
$conn = oci_connect('smarthome', '123', 'localhost/XE');
$error = array();
if (isset($_GET['message'])) {
    $error = htmlentities($_GET['message'], ENT_QUOTES, 'UTF-8');
}
session_start();
if (!isset($_SESSION['ACCOUNT_NO']) || (isset($_SESSION['VERIFY']) && $_SESSION['VERIFY'] == "VERIFY")) {
    session_start();
    session_unset();
    session_destroy();
    header('Location: index.php');
}else{
    $account_no = $_SESSION['ACCOUNT_NO'];
}

$stid = oci_parse($conn, "SELECT * FROM CONSUMER A, BRANCH B where B.BRANCH_CODE = B.BRANCH_CODE AND ACCOUNT_NO = '$account_no'");
oci_execute($stid);
while (($row = oci_fetch_array($stid, OCI_ASSOC+OCI_RETURN_NULLS)) {
    $user = $row;
}


$MONTH_1 = date("F", strtotime("first day of previous month"));
$CONSUMPTION_MONTH_3 = date("Ym", strtotime("first day of previous month"));

$MONTH_2 = date("F", strtotime("first day of previous month -1 months"));
$CONSUMPTION_MONTH_2 = date("Ym", strtotime("first day of previous month -1 months"));

$MONTH_3 = date("F", strtotime("first day of previous month -2 months"));
$CONSUMPTION_MONTH_1 = date("Ym", strtotime("first day of previous month -2 months"));




$CONSUMPTION_MONTH = "201701";
$stid = oci_parse($conn, "SELECT * FROM CONSUMER_APP_DETAIL A, CONSUMPTION_INVENTORY B  WHERE A.ID = B.AP_ID AND B.CONSUMPTION_MONTH = '$CONSUMPTION_MONTH' AND A.ACCOUNT_NO = '$account_no'");
oci_execute($stid);
$i = 0;
$CONSUMPTION_W = 0;

while (($row = oci_fetch_array($stid, OCI_ASSOC+OCI_RETURN_NULLS)) {
  $CONSUMPTION_W += $row["CONSUMPTION_W"];
}
```

```
$CONSUMPTION_MONTH = "201701";
$stid = oci_parse($conn, "SELECT * FROM CONSUMER_APP_DETAIL A, CONSUMPTION_INVENTORY B  WHERE A.ID = B.AP_ID AND B.CONSUMPTION_MONTH = '$CONSUMPTION_MONTH' AND A.ACCOUNT_NO = '$account_no'");
oci_execute($stid);
$i = 0;
$CONSUMPTION_W = 0;

while (($row = oci_fetch_array($stid, OCI_ASSOC+OCI_RETURN_NULLS)) {
  $CONSUMPTION_W += $row["CONSUMPTION_W"];
}

$i = 0;
$AVG_CONSUMPTION = 0;
$stid = oci_parse($conn, "SELECT * FROM SALES_DETAIL where ACCOUNT_NO = '$account_no'");
oci_execute($stid);
$i = 0;
while (($row = oci_fetch_array($stid, OCI_ASSOC+OCI_RETURN_NULLS)) {
  $AVG_CONSUMPTION += $row["AVG_CONSUMPTION"];
  $i++;
}

$AVG = $AVG_CONSUMPTION/$i;

$CONSUMPTION_W = ($CONSUMPTION_W/1000);
$AVG = ($CONSUMPTION_W/$AVG)*100;
$AVG = number_format($AVG, 2);



$i = 0;
$CONSUMPTION_MONTH = "201701";
$stid = oci_parse($conn, "SELECT * FROM SALES_DETAIL WHERE ACCOUNT_NO = '$account_no'");
oci_execute($stid);
$i = 0;
while (($row = oci_fetch_array($stid, OCI_ASSOC+OCI_RETURN_NULLS)) {
  $AVG_CONSUMPTION = $row["AVG_CONSUMPTION"];
```

Source Code of Home Page

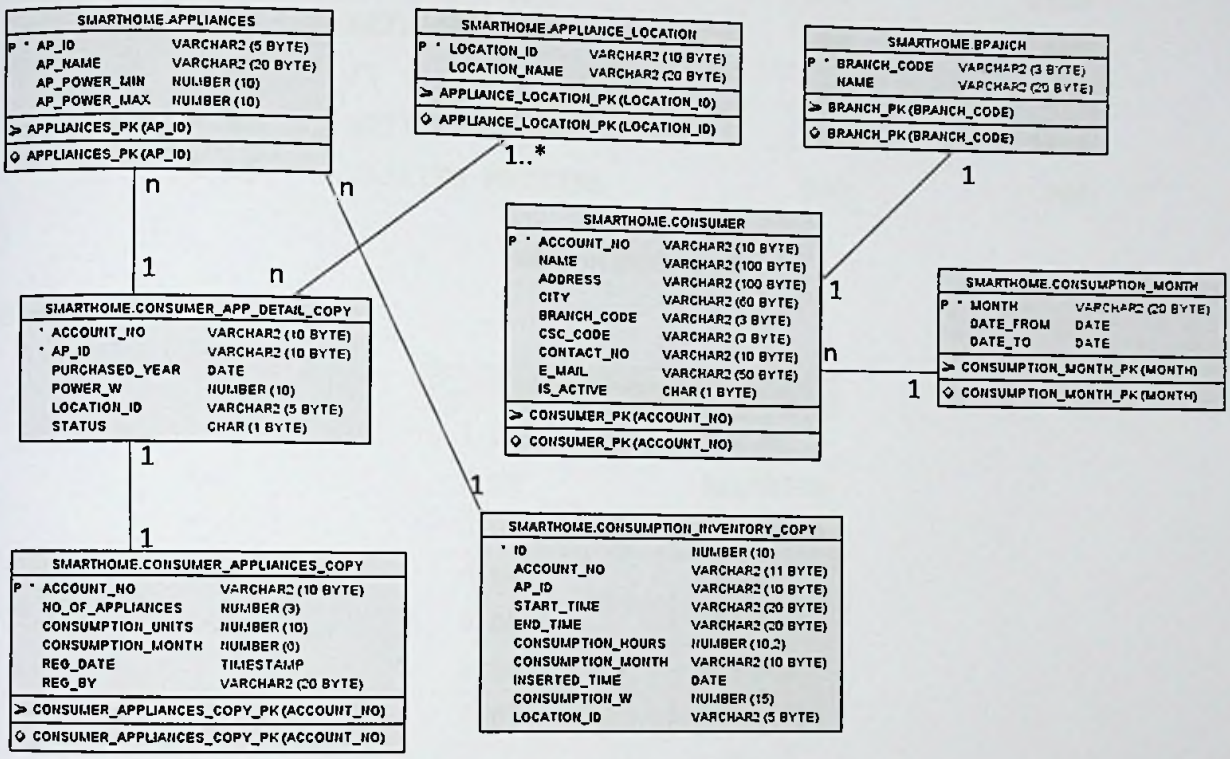
User.php

```
<?php
  session_start();
  if (!isset($_SESSION['ACCOUNT_NO']) || ($_SESSION['USERTYPE'] != 'CONSUMER')) {
    session_start();
    session_unset();
    session_destroy();
    header('location: index.php');
  }else{
    $account_no = $_SESSION['ACCOUNT_NO'];
  }

  $conn=oci_connect('smartbase', '123', 'localhost/XE');
  $res=array();
  if (!$conn) {
      $e = oci_error();
      trigger_error(htmlentities($e['message'], ENT_QUOTES), E_USER_ERROR);
  }

  $stid = oci_parse($conn, "SELECT * FROM CONSUMER A, BRANCH B WHERE A.BRANCH_CODE = B.BRANCH_CODE AND ACCOUNT_NO = '$account_no'");
  oci_execute($stid);
  while ($row = oci_fetch_array($stid, OCI_ASSOC+OCI_RETURN_NULLS)) {
    $user = $row;
  }
?>
<!doctype html>
<html>
  <head>
    <meta charset="utf-8">
    <title>BLOCKS - Bootstrap Dashboard Theme</title>
    <meta name="viewport" content="width=device-width, initial-scale=1.0">
    <meta name="description" content="">
    <meta name="author" content="">

    <!-- Le styles -->
    <link href="assets/css/bootstrap.css" rel="stylesheet">
    <link href="assets/css/main.css" rel="stylesheet">
    <link href="assets/css/font-style.css" rel="stylesheet">
    <link rel="stylesheet" href="assets/css/register.css">

    <script type="text/javascript" src="http://code.jquery.com/jquery-1.10.1.js"></script>
```

```
    <link rel="shortcut icon" href="assets/ico/favicon.ico">
    <link rel="apple-touch-icon-precomposed" sizes="144x144" href="assets/ico/apple-touch-icon-144-precomposed.png">
    <link rel="apple-touch-icon-precomposed" sizes="114x114" href="assets/ico/apple-touch-icon-114-precomposed.png">
    <link rel="apple-touch-icon-precomposed" sizes="72x72" href="assets/ico/apple-touch-icon-72-precomposed.png">
    <link rel="apple-touch-icon-precomposed" href="assets/ico/apple-touch-icon-57-precomposed.png">

    <!-- Font -->
    <link href="http://fonts.googleapis.com/css?family=Raleway:400,100" rel="stylesheet" type="text/css">
    <link href="http://fonts.googleapis.com/css?family=Open+Sans" rel="stylesheet" type="text/css">
  </head>
  <body>

    <!-- Navbar ================================================== -->
    <div class="navbar-nav navbar-inverse navbar-fixed-top">
      <div class="container">
        <div class="navbar-header">
          <button type="button" class="navbar-toggle" data-toggle="collapse" data-target=".navbar-collapse">
            <span class="icon-bar"></span>
            <span class="icon-bar"></span>
            <span class="icon-bar"></span>
          </button>
          <a class="navbar-brand" href="dashboard.php"><image src="assets/img/logo30.png" alt=""> Dashboard</a>
        </div>
        <div class="navbar-collapse collapse">
          <ul class="nav navbar-nav">
            <li><a href="dashboard.php"><i class="icon-home icon-white"></i> Home</a></li>
            <li><a href="appliances.php"><i class="icon-folder-open icon-white"></i> Appliances</a></li>
            <li class="active"><a href="user.php"><i class="icon-user icon-white"></i> User</a></li>
          </ul>
          <ul class="nav navbar-right">
            <li class="active"><a onclick="logOutMe();"> Log Outs</a></li>
          </ul>
        </div>
      </div>
    </div>
```

Source Code of Profile Page

Appendix C – ER diagrams, DB Tables, Use case diagrams, Activity diagrams, etc.



ER Diagram of DB Tables

Appliance Locations

	LOCATION_ID	LOCATION_NAME
1	LOC8	BATHROOM
2	LOC1	ROOM1
3	LOC2	ROOM2
4	LOC3	ROOM3
5	LOC4	ROOM4
6	LOC5	ROOM5
7	LOC6	LIVING
8	LOC7	KITCHEN

Table of Appliance Locations

Appliances

	AP_ID	AP_NAME	AP_POWER_MIN	AP_POWER_MAX
1	A1	FAN	60	100
2	A2	IRON	1000	1800
3	A3	REFRIGERATOR	120	400
4	A4	TV	125	200
5	A5	KETTLE	1200	2400
6	A6	WASHING MACHINE	300	700

Table of Appliances

Branch

	BRANCH_CODE	NAME
1	01	KOTTE
2	02	KELANIYA
3	03	MORATUWA
4	04	GALLE
5	05	KALUTARA
6	06	NEGOMBO
7	07	NUGEGODA

Table of Branches

Consumer

	ACCOUNT_NO	NAME	ADDRESS	CITY	BRANCH_CODE	CONTACT_...	E_MAIL	IS_AC...	CSC_CODE
1	0104294201	S M NAZEER	PLAY GRN*HW OBEY*FURA*111RAJAGIRIYA	NCH20140513*	01	(null)	(null)	N	1
2	0104295205	MANJULA DE SILVA*	7TH LN OBEYSE*FURA*50/4RAJAGIRIYA	NCH20141031*	01	(null)	(null)	N	1
3	0105847302	S UMER	149/11/A KELANIMULLAANGODA	ANGODA	01	(null)	(null)	N	6
4	0106548607	R K SARATHCHANDRA	128/3 SAMARAPALA MAWATHA KENNAKATTANELLAMPITIYA	WELLAMPITIYA	01	(null)	(null)	N	3
5	0105675911	L G AMARADASA	922/1 BOGAHA JUNCTION ROAD GOTHATUWAANGODA	ANGODA	01	(null)	(null)	N	6
6	0105676802	W A P SISIRA KUMARA	434/A BELAGAMA ROAD KELANIMULLAANGODA	ANGODA	01	(null)	(null)	N	6
7	0105678606	U M RAHMATHULLAH	119/7/A KITTAMPAHUWANELLAMPITIYA	WELLAMPITIYA	01	(null)	(null)	N	3
8	0105685811	J ARPUDARAJA	T/73/3/1 PANSALKOTA ROAD MEETHOTAMULLANELLAMPITIYA	WELLAMPITIYA	01	(null)	(null)	N	3
9	0105782501	M N PRIYANGA	100/1/A SAPUMAL PLACE WELIKADARAJAGIRIYA	RAJAGIRIYA	01	(null)	(null)	N	1
10	0105895911	K RUZNA	24/23/2/1/1 PIRIVENA ROADKOLONNAWA	KOLONNAWA	01	(null)	(null)	N	6

Table of Consumer

Consumer Appliance

	ACCOUNT_NO	NO_OF_APPLIANCES	CONSUMPTION_U...	CONSUMPTION_MONTH	REG_DATE	REG_BY
1	0106890410	7	41768	201701	17-MAR-22 12.00.00.000000000 AM	ADMIN
2	0100034605	8	31424	201701	17-MAR-22 12.00.00.000000000 AM	ADMIN
3	0100048806	7	30537	201701	17-MAR-22 12.00.00.000000000 AM	ADMIN
4	0100049609	8	6129	201701	17-MAR-22 12.00.00.000000000 AM	ADMIN
5	0100057903	9	3356	201701	17-MAR-22 12.00.00.000000000 AM	ADMIN
6	0100006401	7	3076	201701	17-MAR-22 12.00.00.000000000 AM	ADMIN
7	0100030502	8	1494	201701	17-MAR-22 12.00.00.000000000 AM	ADMIN
8	0106889607	8	1195	201701	17-MAR-22 12.00.00.000000000 AM	ADMIN
9	0100097602	10	1164	201701	17-MAR-22 12.00.00.000000000 AM	ADMIN
10	0106895305	10	1007	201701	17-MAR-22 12.00.00.000000000 AM	ADMIN

Table of Consumer Appliance

Consumption Inventory

	ID	ACCOUNT_NO	AP_ID	START_TIME	END_TIME	CONSUMPTION_HOURS	CONSUMPTION_MONTH	INSERTED_TIME	CONSUMPTION_W	LOCATION_ID
1	18	0106901905	A4	08:17:44	09:01:44	0.44	201701	01-DEC-16	57	LOC1
2	23	0100046210	A4	14:44:57	15:46:57	1.02	201701	01-DEC-16	82	LOC5
3	32	0106887011	A4	17:47:12	19:03:12	1.16	201701	01-DEC-16	103	LOC1
4	35	0106898407	A4	17:47:10	18:08:10	1.33	201701	01-DEC-16	133	LOC5
5	43	0106880906	A1	11:57:56	13:16:56	1.59	201701	01-DEC-16	137	LOC7
6	49	0106880906	A2	08:27:29	08:43:29	0.16	201701	01-DEC-16	198	LOC2
7	30	0106898407	A1	00:25:57	04:34:57	4.09	201701	01-DEC-16	258	LOC3
8	13	0100046210	A1	08:55:54	13:07:54	4.12	201701	01-DEC-16	264	LOC3
9	47	0106894106	A1	17:55:04	21:18:04	4.03	201701	01-DEC-16	265	LOC2
10	29	0106901905	A1	18:57:20	22:56:20	4.39	201701	01-DEC-16	279	LOC1

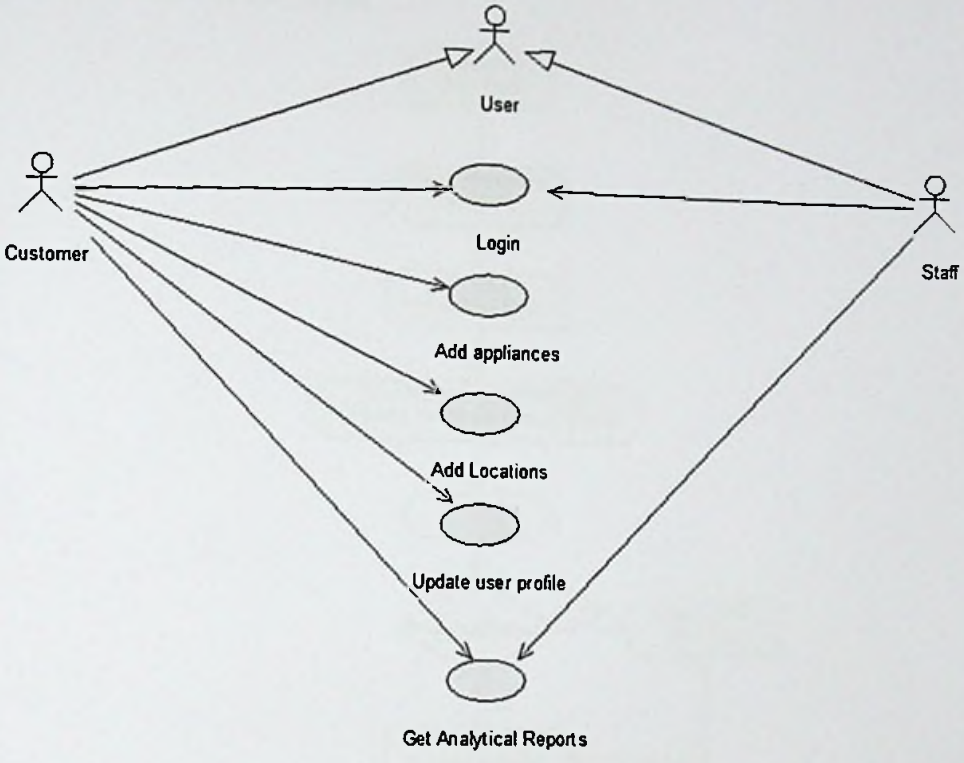
Table of Consumption Inventory

Consumption Month

	MONTH	DATE_FROM	DATE_TO
1	201703	01-MAR-17	31-MAR-17
2	201702	01-FEB-17	28-FEB-17

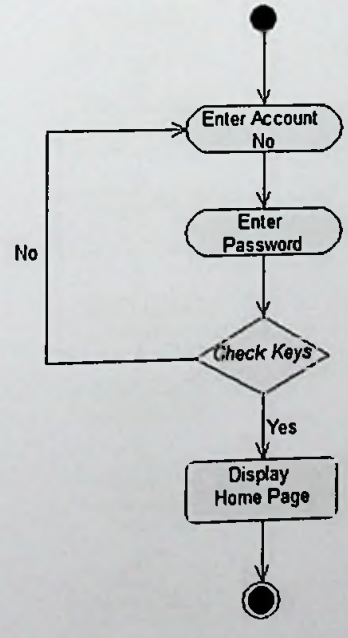
Table of Consumption Month

Use Case diagram - DOMEMS



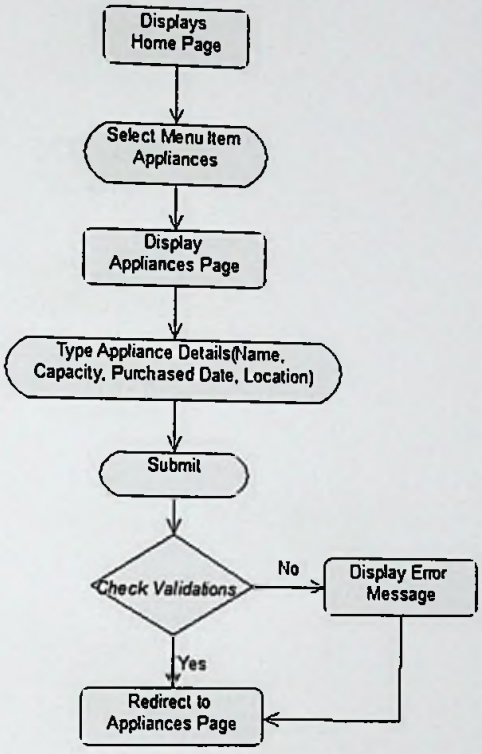
Use Case Diagram-DOMEMS

Login – Activity Diagram



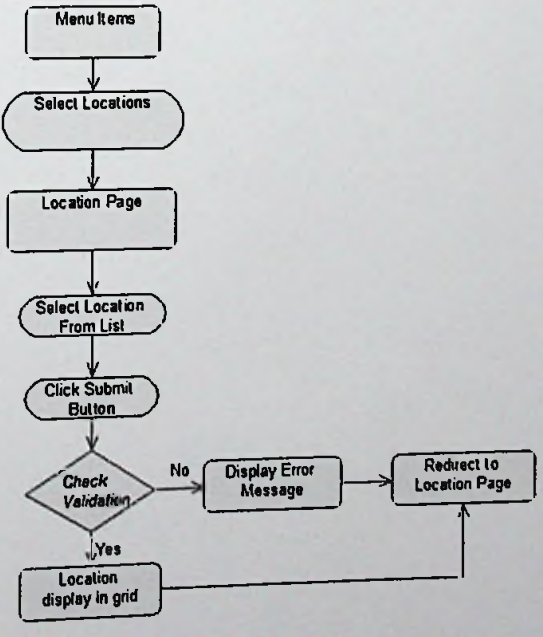
Activity Diagram - Login

Add Appliances – Activity Diagram



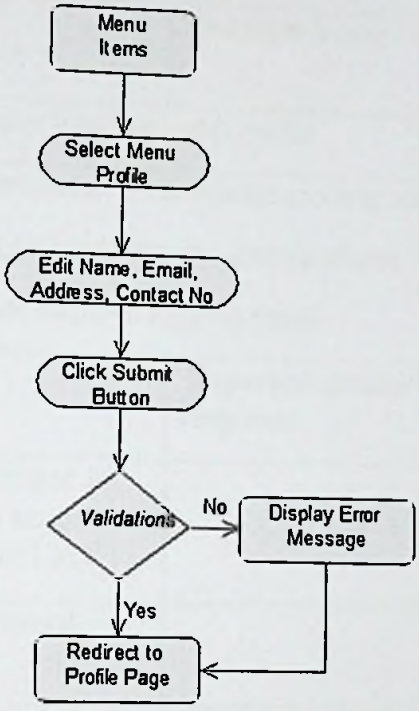
Activity Diagram - Add Appliance

Add Location – Activity Diagram



Activity Diagram - Add Location

Update Profile – Activity Diagram



Activity Diagram - Update Profile

Appendix D – Test cases were used to test the system

Test case No	01	Test case name	User Login- customer portal	
Short description	Test the user logging – successful			
Pre-Condition	Current username is electricity account no("0106901905") Password receives into the mobile phone The system displays logging page			
Step	Action	Expected system response	Pass/Fail	Comment
1	Enter username as electricity account no("0106901905")			
2	Enter password received			
3	Click the logging button	Displays the home page	Pass	
Post condition	User logged into the system			

Test case No	02	Test case name	User Login- customer portal	
Short description	Test the user logging – failed			
Pre-Condition	Current username is electricity account no Password receives into the mobile phone The system displays logging page			
Step	Action	Expected system response	Pass/Fail	Comment
1	Enter username as electricity account no("01106901905")	Display error message as invalid consumer		
2	Enter a wrong			

	password			
3	Click the logging button	Displays error message and ask to re-enter	Pass	
Post condition	User redirect to the logging page			

Test case No	03	**Test case name**	Add new appliances- customer portal	
Short description	Test adding new appliances - success			
Pre-Condition	User logging to the system Navigate to appliance creation page The system displays appliance creation page			
Step	**Action**	**Expected system response**	**Pass/Fail**	**Comment**
1	Enter appliance name (Ex: Fan, Iron, etc.)	Move into next	Pass	
2	Enter the capacity (numeric value Ex: 120, 130, etc.)	Move into next	Pass	
3	Select the purchased date	Move into next	Pass	
4	Select the location	Move into next	Pass	
5	Click submit button	Displays success message and refresh the page	Pass	
Post condition	New appliance store in appliances table			

Test case No	04	Test case name	Add new appliances- customer portal	
Short description	Test adding new appliances - failed			
Pre-Condition	User logging to the system Navigate to appliance creation page The system displays appliance creation page			
Step	Action	Expected system response	Pass/Fail	Comment
1	Enter appliance name (Ex: Fan, Iron, etc.)	Move into next	Pass	
2	Enter the capacity (decimal value Ex: 120.5, 130.6, etc.)	Displays error message and refresh the field	Pass	
3	Select the purchased date	Move into next	Pass	
4	Select the location as empty			
5	Click submit button	Displays error message and refresh the page	Pass	
Post condition	User redirect to the appliances creation page			

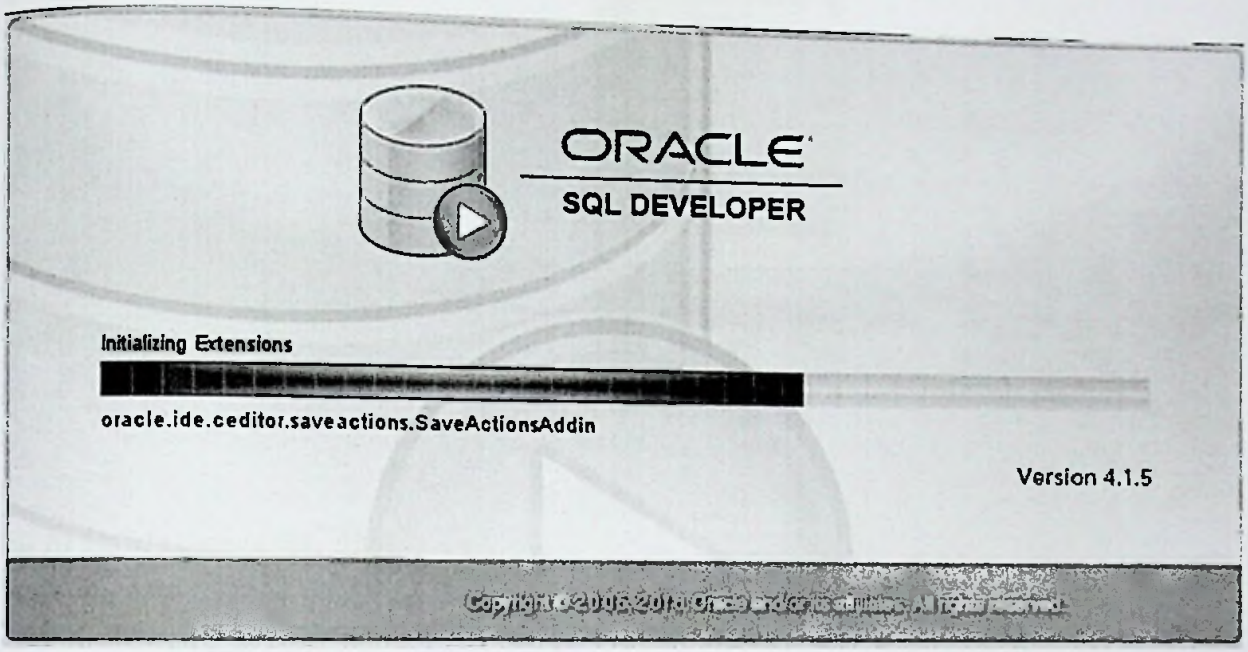
Test case No	05	Test case name	Map locations in home- customer portal	
Short description	Map new location – adding location			
Pre-Condition	User logging to the system Navigate to locations page The system displays locations page			
Step	**Action**	**Expected system response**	**Pass/Fail**	**Comment**
1	Select location	Move into next	Pass	
2	Click submit button	Displays the success message and refresh the page	Pass	
Post condition	User redirect to the location page			

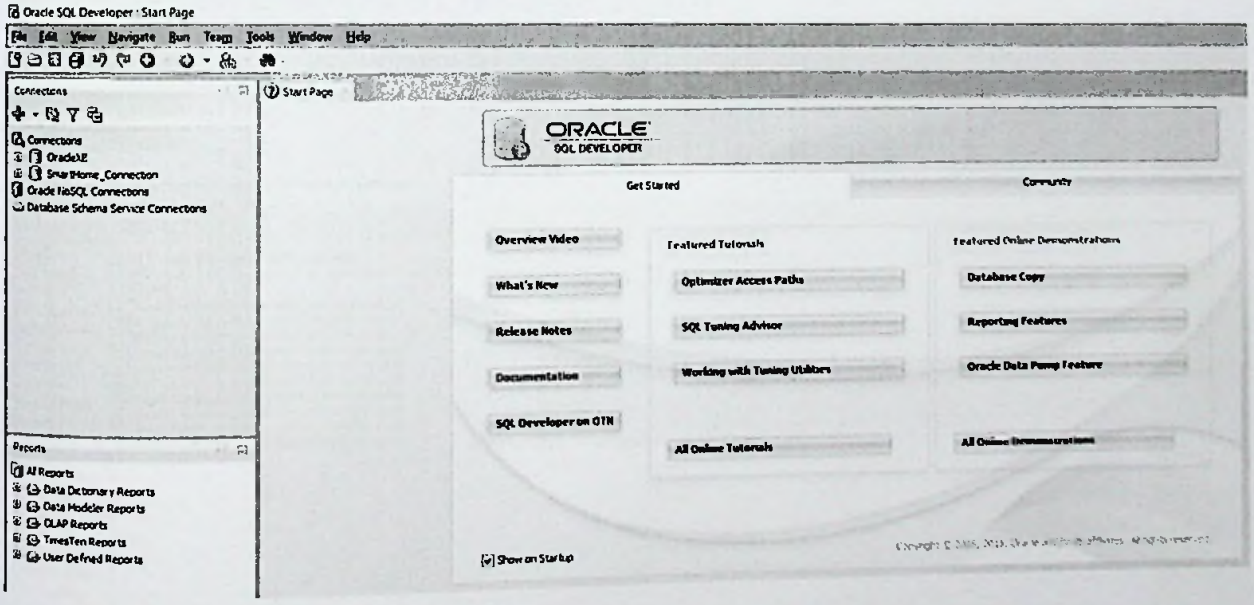
Test case No	06	Test case name	Remove locations in home- customer portal	
Short description	Remove location already mapped			
Pre-Condition	User logging to the system Navigate to locations page The system displays locations page			
Step	**Action**	**Expected system response**	**Pass/Fail**	**Comment**
1	Select location from grid			
2	Click delete action	Displays the success message and refresh the page	Pass	
Post condition	User redirect to the location page			

Test case No	07	Test case name	Edit profile data	
Short description	Update consumer details			
Pre-Condition	User logging to the system Navigate to profile page The system displays locations page			
Step	Action	Expected system response	Pass/Fail	Comment
1	Edit name	Move into next	Pass	
2	Edit email address	Move into next	Pass	
3	Edit contact no	Move into next	Pass	
4	Click update button	Displays the success message and refresh the page	Pass	
Post condition	User redirect to the profile page			

Appendix E – Images explaining the tools were used

Oracle Database



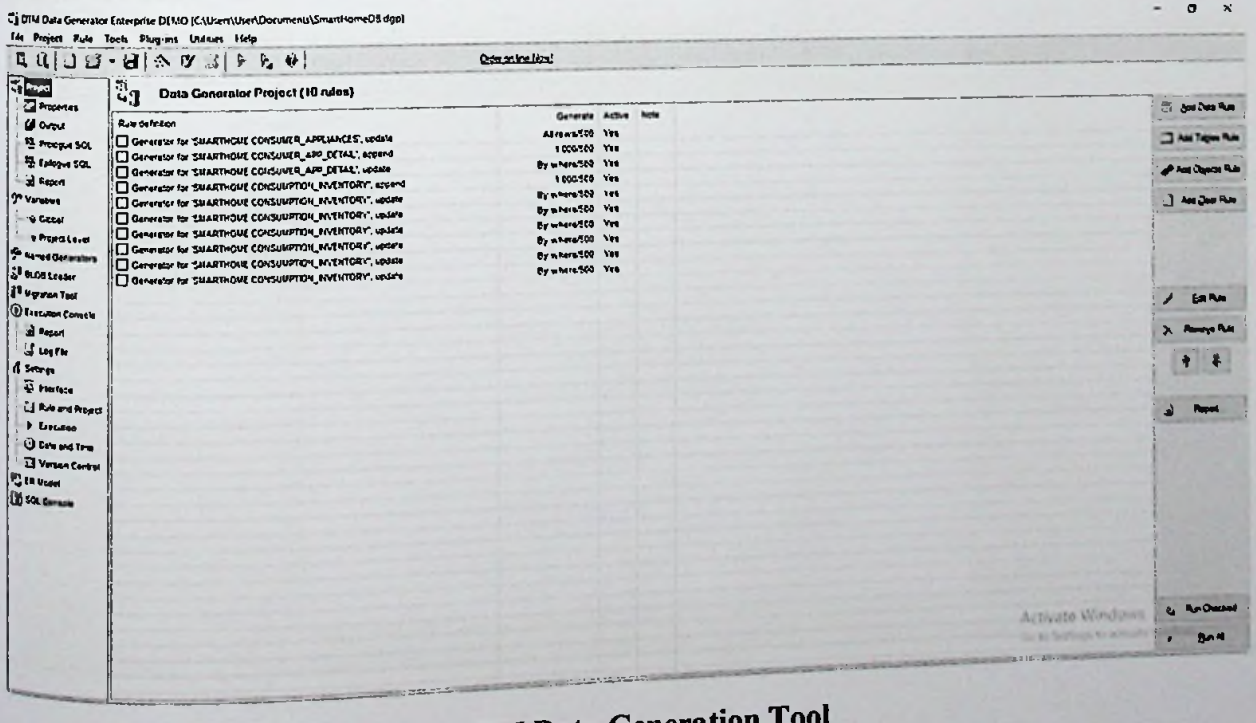


Oracle Database

Wamp Server

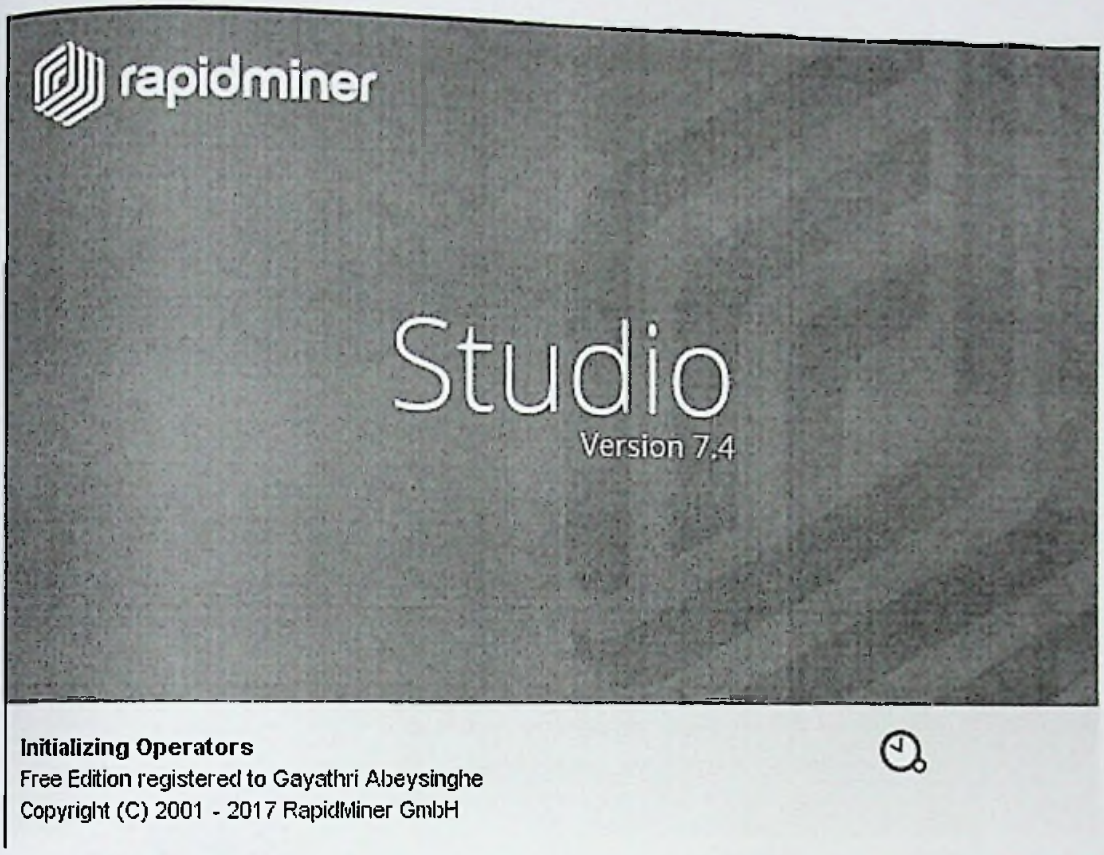
Wamp Server

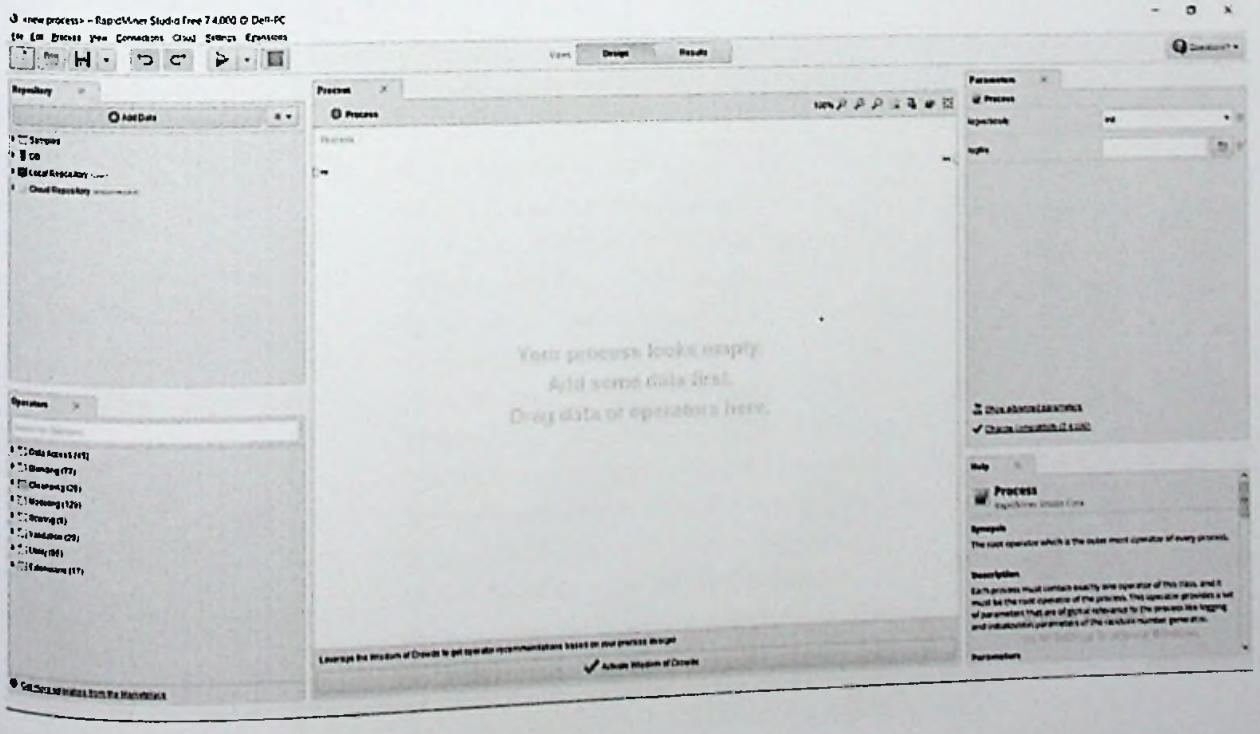
DTM Data Generation Tool

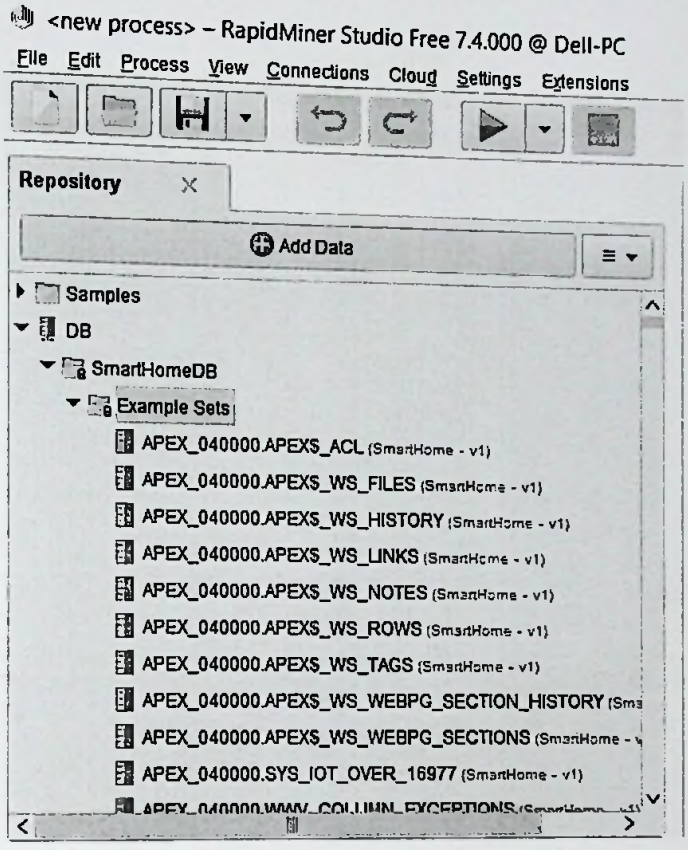


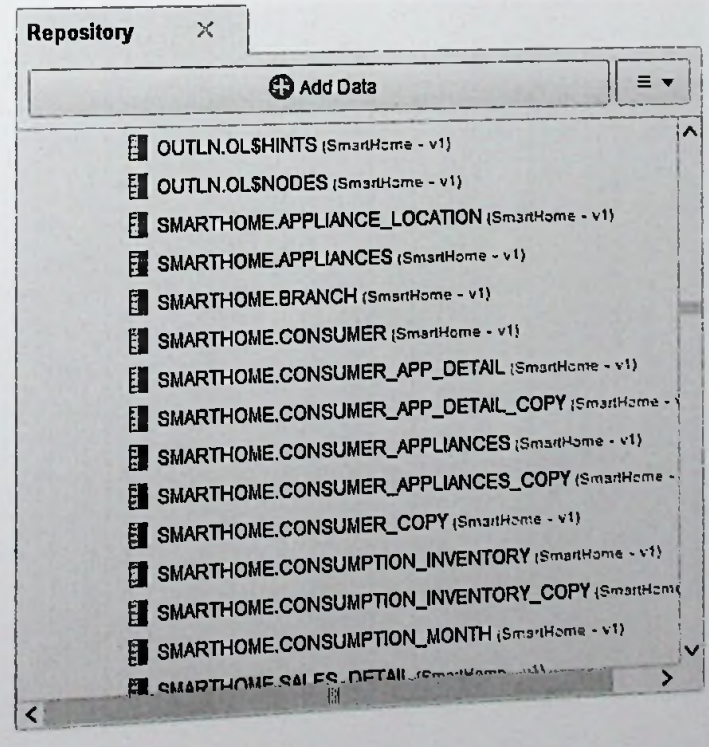
DTM Data Generation Tool

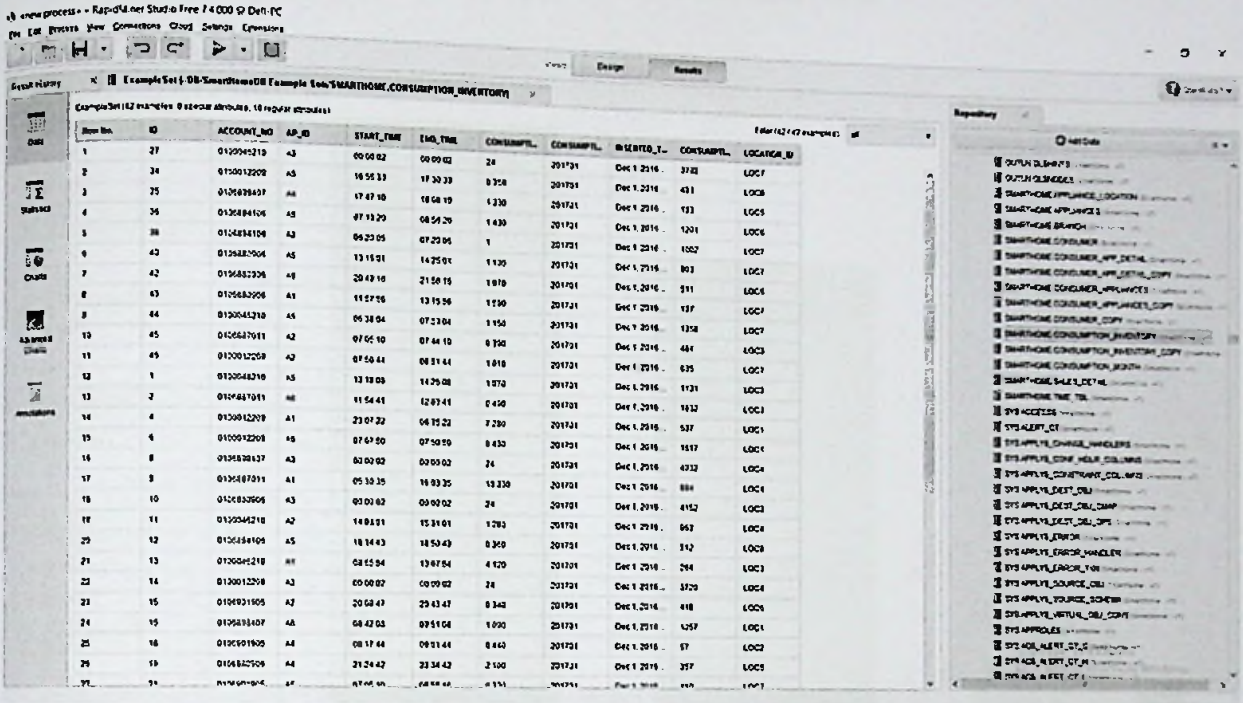
RapidMiner Studio





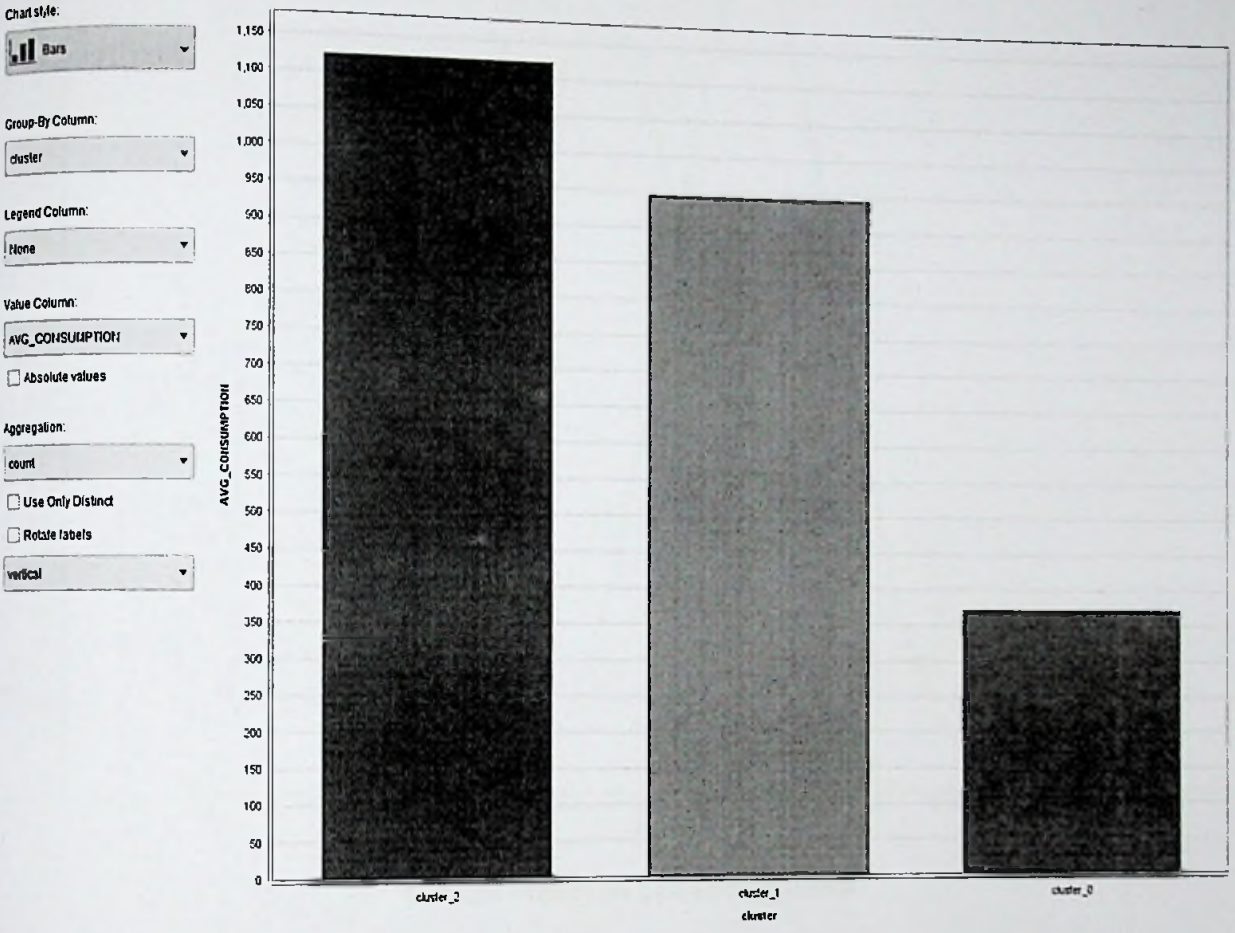

<new process> – RapidMiner Studio Free 7.4.000 @ Dell-PC
File Edit Process View Connections Cloud Settings Extensions
Repository
Add Data
Samples
DB
SmartHomeDB
Example Sets
APEX_040000.APEX$_ACL (SmartHome - v1)
APEX_040000.APEX$_WS_FILES (SmartHome - v1)
APEX_040000.APEX$_WS_HISTORY (SmartHome - v1)
APEX_040000.APEX$_WS_LINKS (SmartHome - v1)
APEX_040000.APEX$_WS_NOTES (SmartHome - v1)
APEX_040000.APEX$_WS_ROWS (SmartHome - v1)
APEX_040000.APEX$_WS_TAGS (SmartHome - v1)
APEX_040000.APEX$_WS_WEBPG_SECTION_HISTORY
APEX_040000.APEX$_WS_WEBPG_SECTIONS
APEX_040000.SYS_IOT_OVER_16977 (SmartHome - v1)

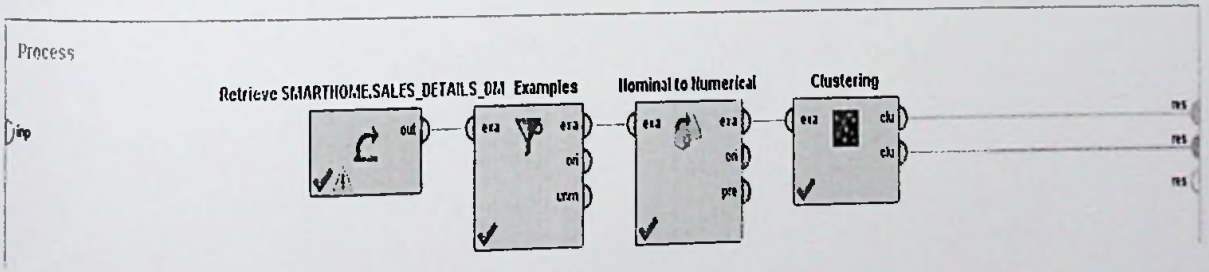

Repository
Add Data
OUTLN.OL$HINTS (SmartHome - v1)
OUTLN.OL$NODES (SmartHome - v1)
SMARTHOME.APPLIANCE_LOCATION (SmartHome - v1)
SMARTHOME.APPLIANCES (SmartHome - v1)
SMARTHOME.BRANCH (SmartHome - v1)
SMARTHOME.CONSUMER (SmartHome - v1)
SMARTHOME.CONSUMER_APP_DETAIL (SmartHome - v1)
SMARTHOME.CONSUMER_APP_DETAIL_COPY
SMARTHOME.CONSUMER_APPLIANCES (SmartHome - v1)
SMARTHOME.CONSUMER_APPLIANCES_COPY
SMARTHOME.CONSUMER_COPY (SmartHome - v1)
SMARTHOME.CONSUMPTION_INVENTORY (SmartHome - v1)
SMARTHOME.CONSUMPTION_INVENTORY_COPY
SMARTHOME.CONSUMPTION_MONTH (SmartHome - v1)

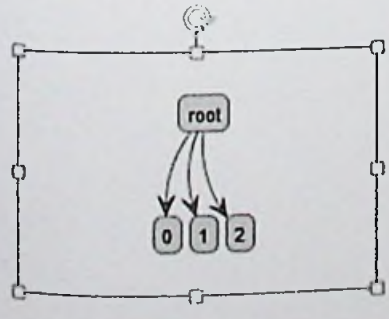


Rapid Miner Studio Tool

Appendix G – Data Analysis of DOMEMS

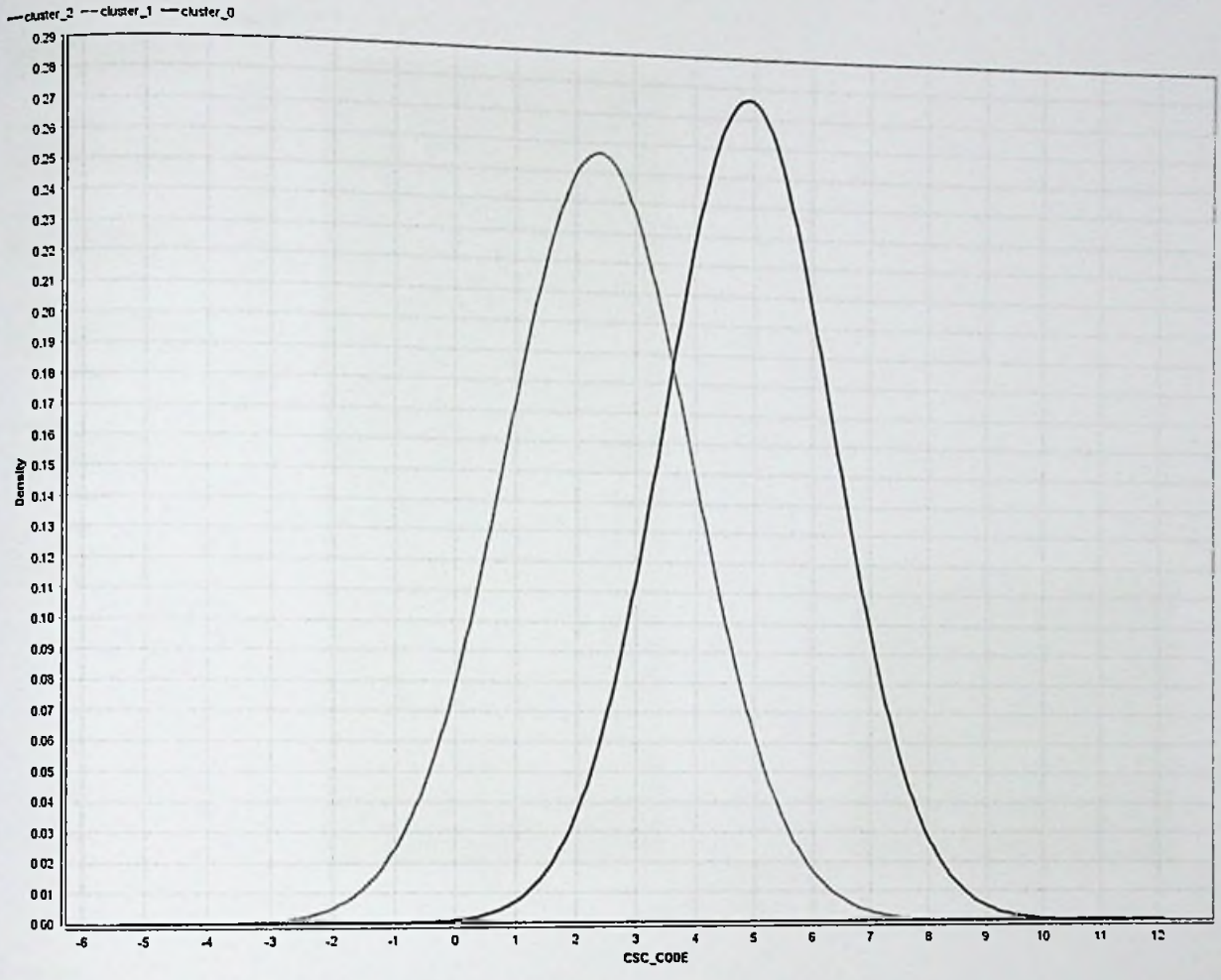




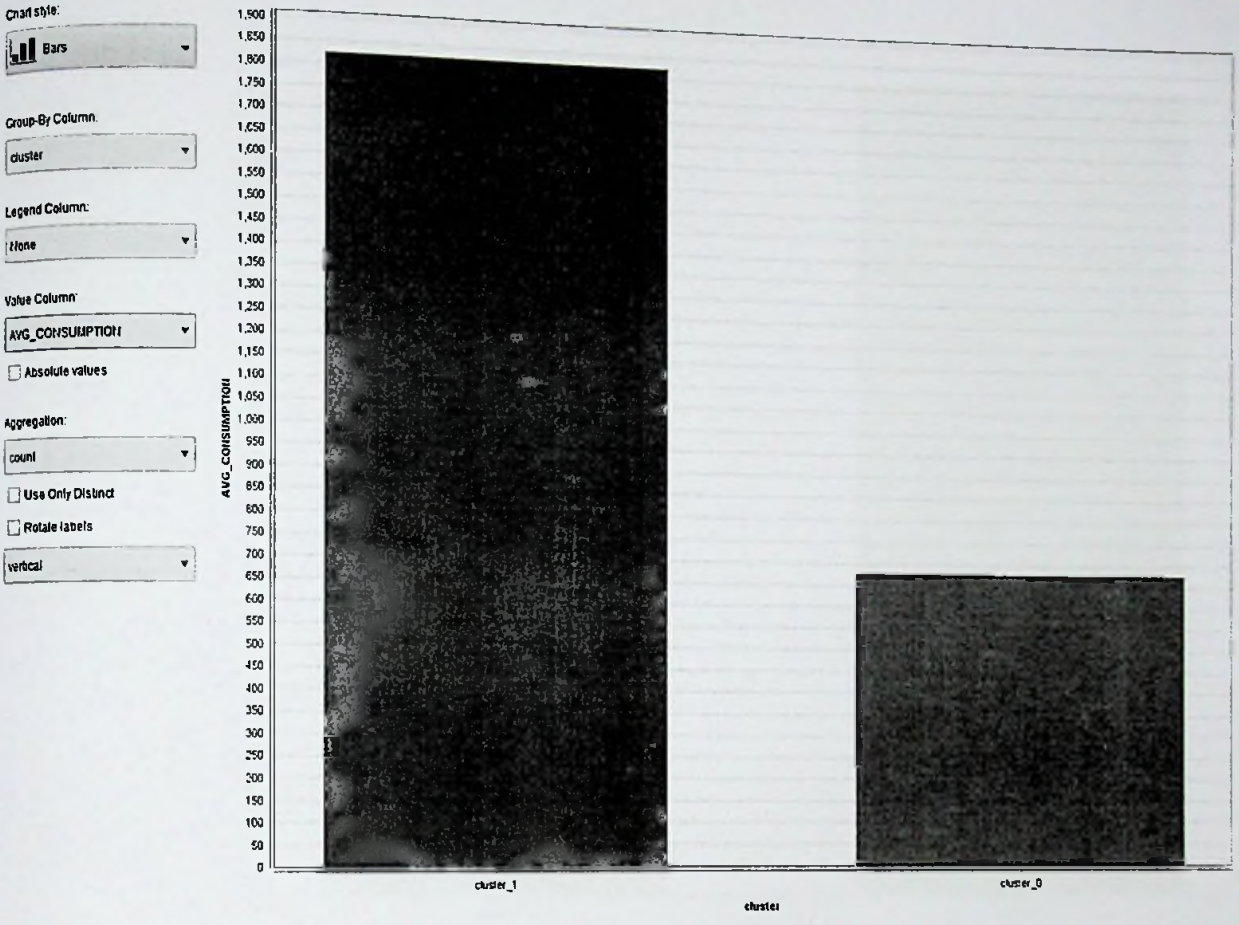


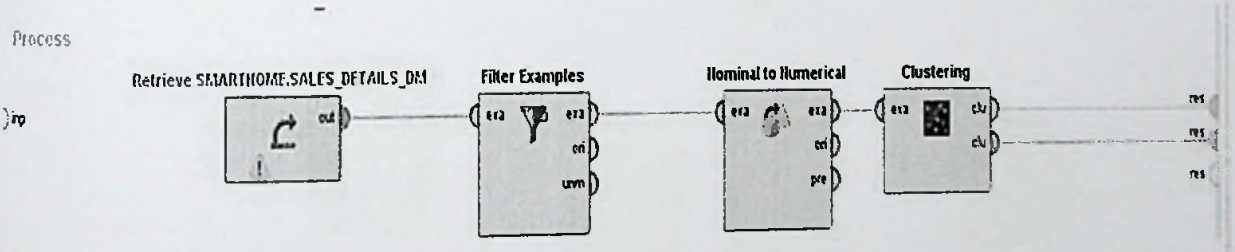
Cluster Model

```
Cluster 0: 372 items
Cluster 1: 945 items
Cluster 2: 1123 items
Total number of items: 2440
```



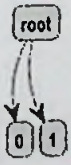
Cluster Analysis of January Data



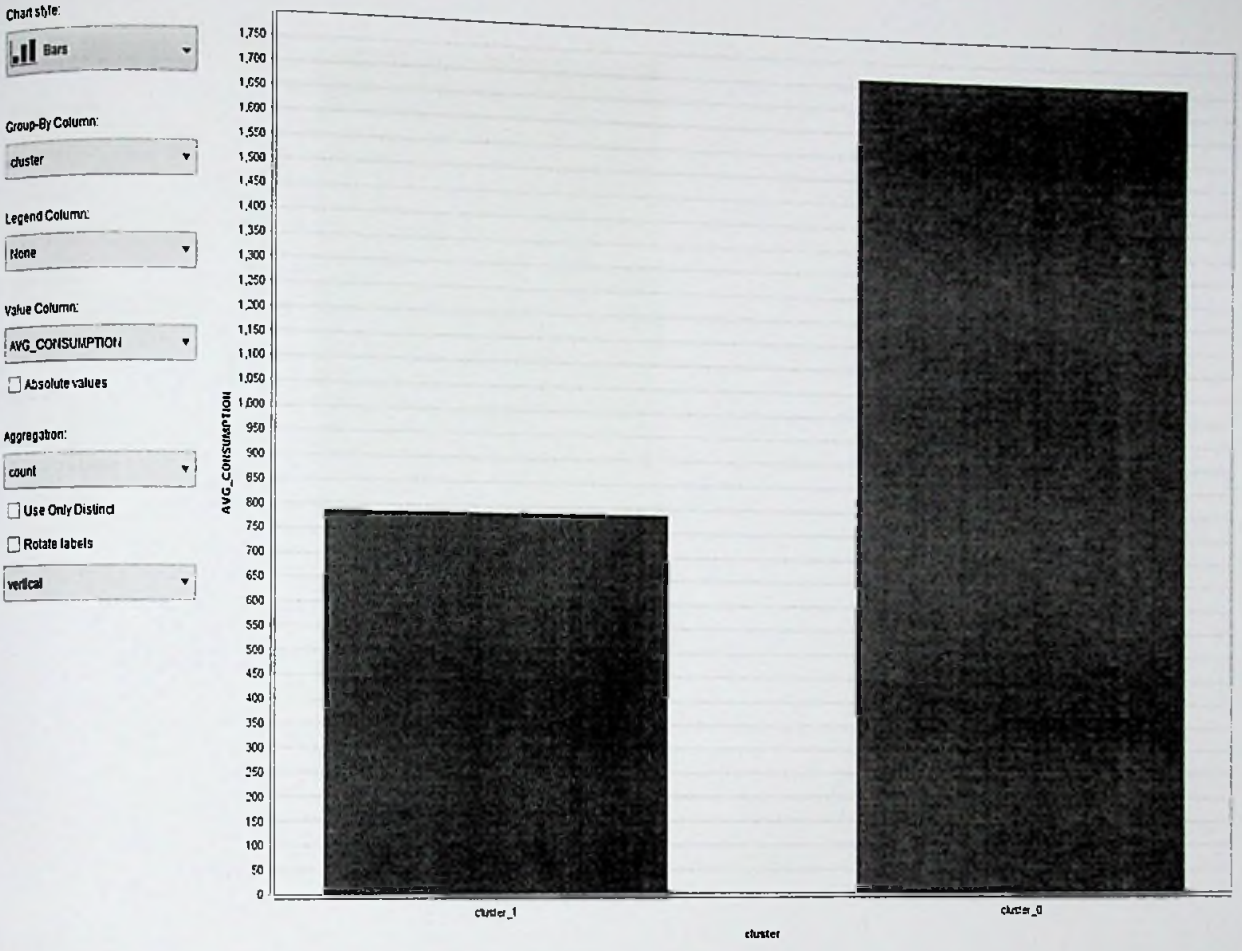


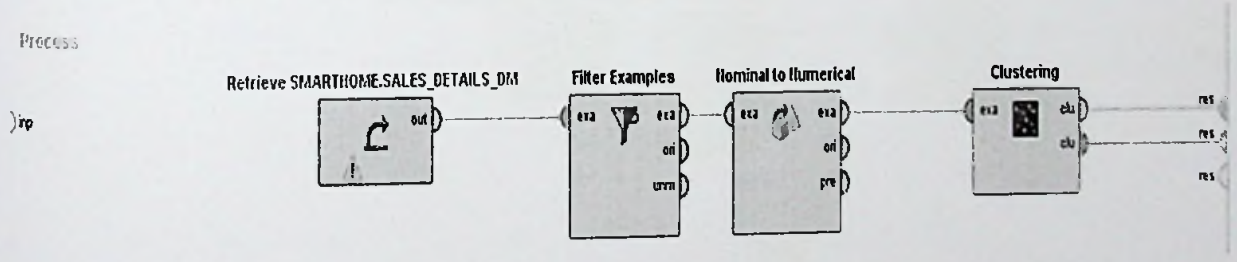
Cluster Model

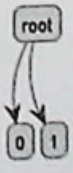
```
Cluster 0: 677 items
Cluster 1: 1823 items
Total number of items: 2500
```



Cluster Analysis of February Data



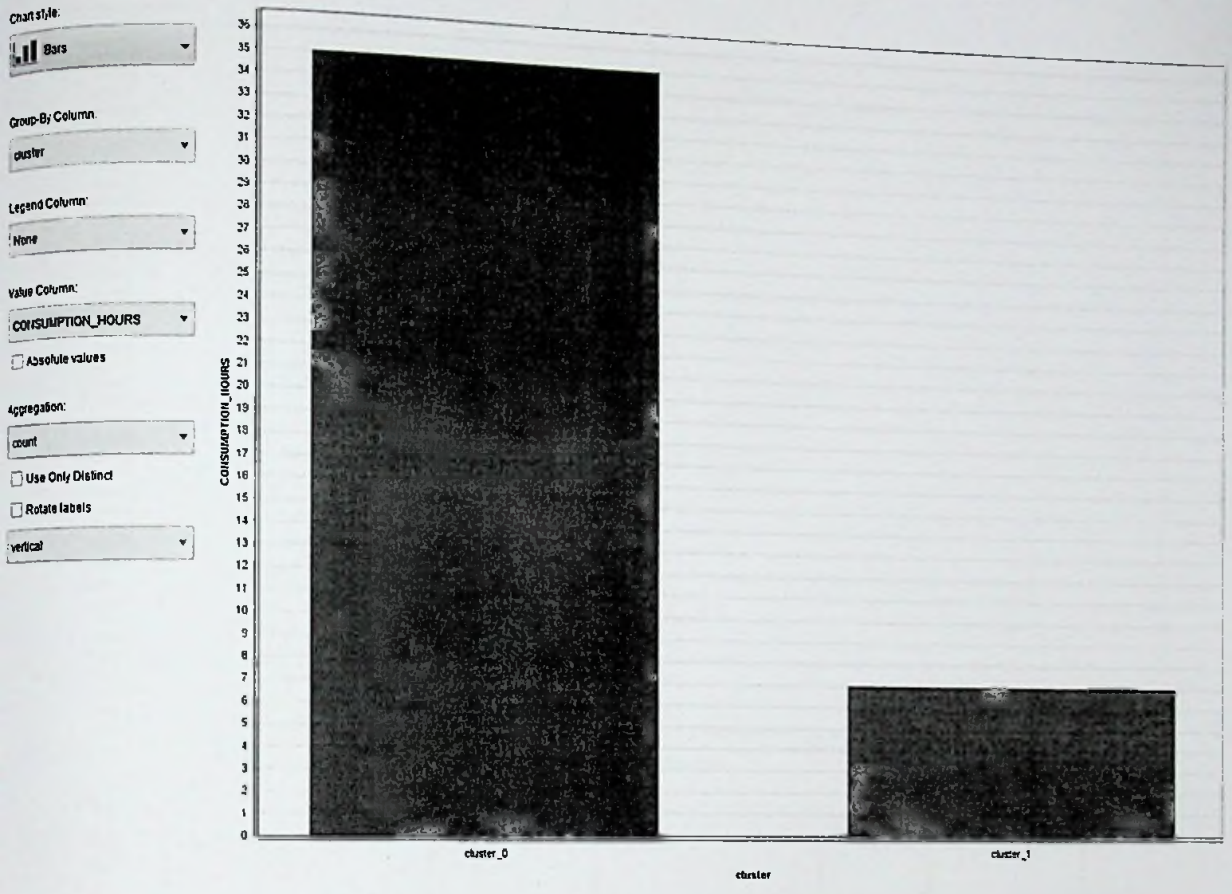


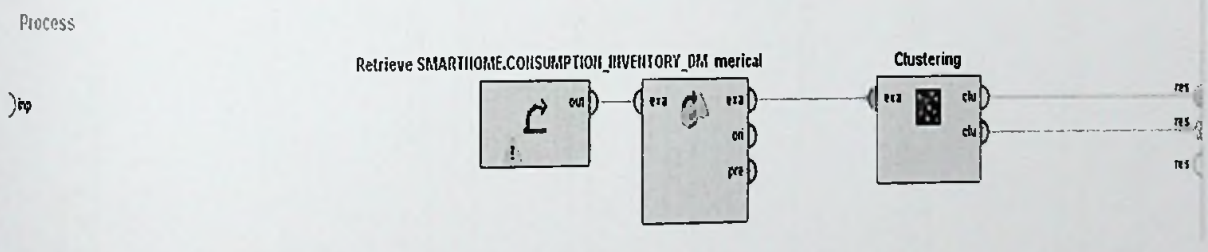


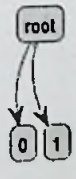
Cluster Model

```
Cluster 0: 1713 items
Cluster 1: 787 items
Total number of items: 2500
```

Cluster Analysis of March Data

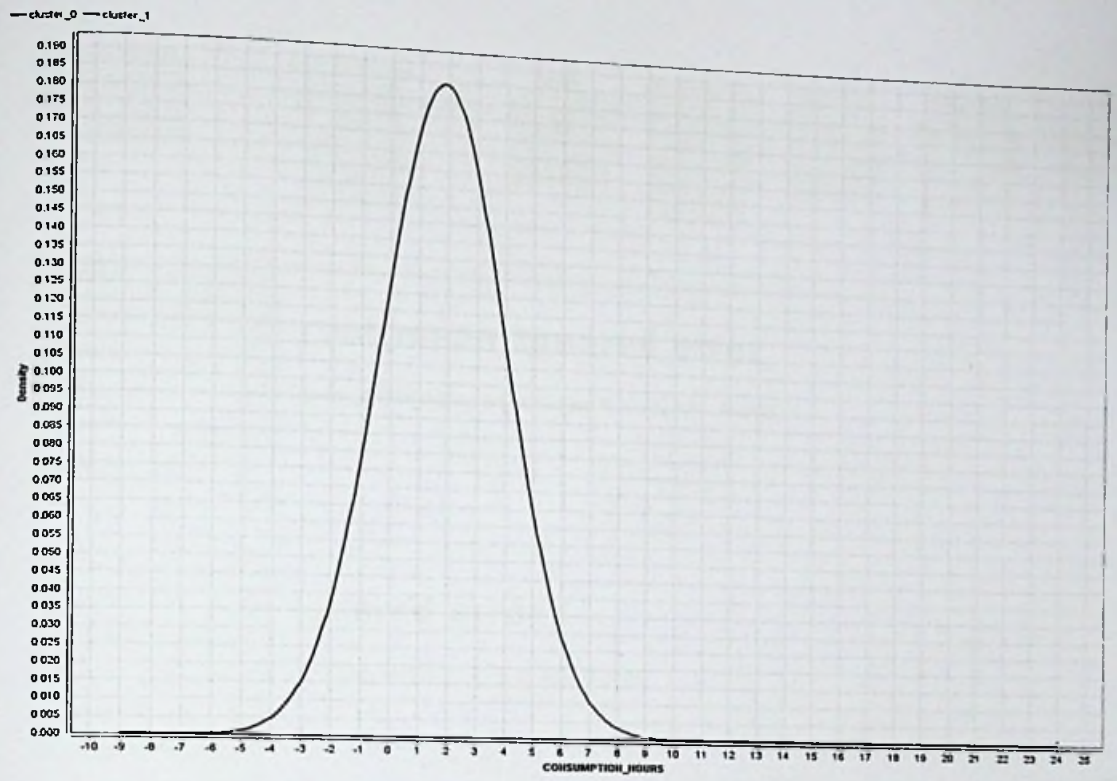


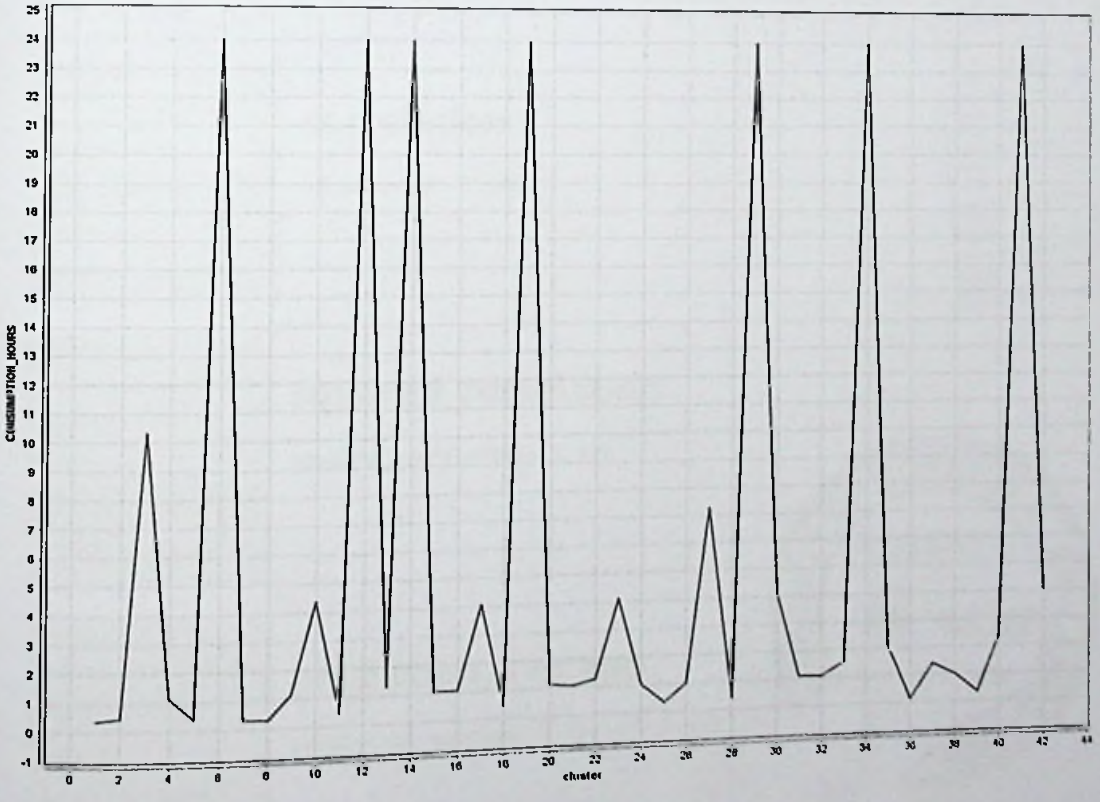




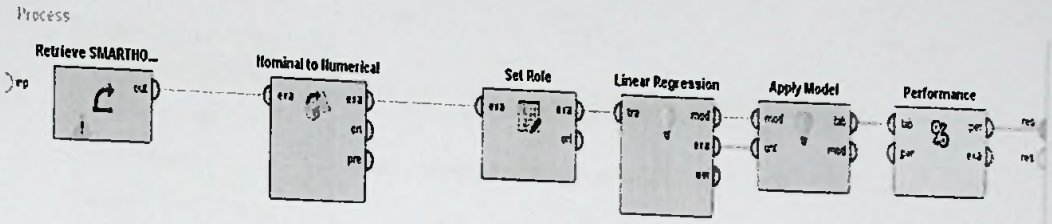
Cluster Model

```
Cluster 0: 35 items
Cluster 1: 7 items
Total number of items: 42
```





Cluster Analysis of Consumption Inventory



Criterion
- root mean squared error
- squared error
- correlation
- squared correlation
- prediction average

root_mean_squared_error

```
root_mean_squared_error: 0.000 +/- 0.000
```

Criterion
- root mean squared error
- squared error
- correlation
- squared correlation
- prediction average

squared_error

```
squared_error: 0.000 +/- 0.000
```


Criterion
- root mean squared error
- squared error
- correlation
- squared correlation
- prediction average

correlation

```
correlation: 1.000
```

Criterion
- root mean squared error
- squared error
- correlation
- squared correlation
- prediction average

squared_correlation

```
squared_correlation: 1.000
```


Criterion
- root mean squared error
- squared error
- correlation
- squared correlation
- prediction average

prediction_average

```
prediction_average: 5.537 +/- 8.483
```

Linear Regression Analysis for Consumption Hours

Criterion
- root mean squared error
- squared error
- correlation
- squared correlation
- prediction average

root_mean_squared_error

```
root_mean_squared_error: 1353.304 +/- 0.000
```

Criterion
- root mean squared error
- squared error
- correlation
- squared correlation
- prediction average

squared_error

```
squared_error: 1831432.139 +/- 3668022.329
```

Criterion
- root mean squared error
- squared error
- correlation
- squared correlation
- prediction average

correlation

```
correlation: 0.000
```

Criterion
- root mean squared error
- squared error
- correlation
- squared correlation
- prediction average

squared_correlation

```
squared_correlation: 0.000
```

Criterion
- root mean squared error
- squared error
- correlation
- squared correlation
- prediction average

prediction_average

```
prediction_average: 1209.167 +/- 1353.304
```

Linear Regression Analysis for Consumption Watts