

College of Business,

Technology and   
Engineering

MSc Dissertation Report

**"Enhancement of Smart Home Automation Architecture"**

A dissertation submitted in partial fulfilment of the requirements of Sheffield Hallam University for the degree of Master of Science in [**Big Data Analytics**]

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**Abstract**

The service of smart home is considered as key integral part of smart grid energy consumption. Smart home is organic combination of different subsystems which is associated with home life by advanced form of technologies. Smart home is regarded as the utilization of computing, automation as well as display technologies that must be connected through networks of several types of facilities for meeting automation requirements. It can be said that smart homes save huge amount of energy through keeping proper track of the utilizations of rooms and the scheduled time to use them with the help of IoT. Now-a-days, with increasing demands of the energy consumption the high energy bills are making headaches. And because of the traditional homes it is getting uncontrollable to minimize the use of energy consumption. The smart systems can keep proper track of the desired number of rooms are occupied by the residents along with ensuring that temperature existing in the room is sufficiently comfortable as per the requirements of the resident. The beauty of possible way in which the smart homes can save the consumption of energy is based on elegance of it. The requirement of implementing the approach of smart home technology can be considered very necessary for the shortage of intelligent applications. This specific research paper specifically focuses on delivering a clear concept about multiple beneficial aspects of utilizing smart home technology in the place of traditional technology. With the help of smart home technology several individuals can be able to connect to their home devices through a smart phone or tablet, which can be very effective in gaining more control over their homes and surroundings. The definite technology of the smart home also allows the people to control all types of home operations remotely and helps in enhancing luxury in lifestyles.

Keywords: (IoT, smart homes, energy consumption, technologies, devices)

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Finally, I would like to thank God for empowering me with fill strength to complete this research work within scheduled time.

**Declaration**

I declare that this project, “Enhancement of Smart Home Automation Architecture”, is submittedby me, Komal Pandharinath Dhondkar to the Sheffield Hallam University. Furthermore, I affirm that this work is my own and has not been submitted to this university or any other institution for the purpose of receiving a degree.

**Date:** 13/05/2022 **Signature:** A picture containing text, document

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### Chapter.1: Introduction

### 1.1 Research Background

Smart home applications can typically be considered ubiquitous and have obtained fame due to the increasing utilization of IoT-based technology. The uprising of technologies has played a major role in making homes more efficient, secure, and convenient. The requirement of implementing the approach of smart home technology can be considered very necessary for the shortage of intelligent applications. This specific research paper specifically focuses on delivering a clear concept about multiple beneficial details of utilizing smart home technology in the place of traditional technology. A smart home is a specific application or implementation of IoT that could play a major role in enabling monitor multiple home activities from any location. The concept of smart home technology will also be discussed in this paper, which specifically refers to any set of systems, appliances, and devices that are typically networked with each other that can be remotely or independently controlled (Nelson and Allen, 2018). When the technology of the home performs together in a single system, it can typically be described as a connected home. For example, the lights, speakers, security cameras, appliances, locks, TVs, and thermostats of a home are connected to a single system from the smart phone. In order to implement an effective smart home technology, there is some major requirement that needs to be taken into consideration, such as Wi-Fi and internet connection, tablet or smart phone in order to control the home devices, wireless network or cable network, devices need to connected utilizing similar wireless standard, and more (Li et al., 2021).

### 1.2 Research Rationale

In this current generation, with the rising occurrence of personal threats and burglary to property damage and home occupancy, it is very important to obtain a more effective system to maintain security track in the environment and home (Del Rio, Sovacool and Martiskainen, 2021). In this current era, security and safety over lives and properties can typically be considered the major concerns that need to be prioritized. For this reason, a home should typically implement a more effective and intelligent system to control, monitors remotely, and report different activities to the occupants. To achieve safety, convenience, and security and manage a home, the requirement specifically rises for a system of intelligent homes. Unlike traditional homes, the automation of the smart home can be very effective in allowing switching into high-tech luxury and functionality that specifically was not possible in the past. With the help of smart home technology, people can connect to all their home devices through a smartphone, which can be very effective in gaining more control over their homes and surroundings (Li et al., 2021). Alternately, smart home technology can also be very effective in enhancing the flexibility of new appliances and devices. Besides all, this specific technology can also have a significant impact in maximizing the security of the home. After implementing the multiple features of surveillance and security in the network of smart homes, the security of the home can skyrocket. The technology of the smart home also allows people to control all the home functions remotely and helps in enhancing luxury in lifestyles. Increasing energy efficiency is another beneficial aspect to which smart home technology contributed a lot (Nelson and Allen, 2018). Implementing automation can be considered the major reason to increase energy efficiency as it can sense the requirements of energy.

### 1.3 Research Problem

There are different kinds of complications associated with the traditional home, which can typically be eliminated with the assistance of smart home technology. The concept of technology is improving day by day and obtaining a smart home can specifically be considered a necessity in this generation. People tend to like the concept of automation. With traditional home technology, people were not capable of controlling all devices and appliances of their houses through a single device. Alternately, with the help of smart home technology, people can control their home devices, including cooling and heating systems and all the lights of the homes (Del Rio, Sovacool and Martiskainen, 2021). Older persons in the house may face different kinds of difficulties while moving, where this technology allows them to control the systems of the entire house through a single device. In this current generation, security over properties than persons can be considered the major concern of all, where the technology of smart home can be very effective in delivering peace of mind as this technology allows people to utilize the technology in checking doors, windows, sensors and more. The electricity and power bills are other major concerns of utilizing traditional homes, where the smart home technology ensures to save the entire electricity and reduce water and power bills of the houses (Bourazeri and Stumpf, 2018). On the other hand, in the case of traditional homes, people tend to be lazy or careless about the wastage of electricity, whereas automation in the smart home helps in reducing electricity consumption.

Considering the resolution for the modern problem the next steps in this study will be to reduce hardware infectivity and to combine advanced algorithms and methodologies to deliver sensing technologies (Viani & Rocca, 2013). The contrasted paper focused primarily on home data analysis approaches. They essentially gathered and exploited sensor data for each service domain (Kim & Lee, 2015).

### 1.4 Research Scope and Significance

This specific research paper has played a vital role in identifying and analysing the multiple reasons for utilizing different beneficial aspects of smart home technology compared to traditional homes. With the help of this research paper, readers could easily identify the reason to switch their home technology from traditional to smart in order to improve the home environment in multiple aspects such as automation, security, controls, energy consumption, and more (Bourazeri and Stumpf, 2018). This specific search paper also helps to identify the importance of obtaining automation in the process of reducing energy consumption in several areas of homes.

### 1.5 Research Structure

This specific section of the introduction has specifically focused on delivering the background of the concept of utilizing the effectiveness of smart home technology. The section on research rationale has helped this paper to identify the impact of the research paper, and the section on the research problem has effectively identified all the areas that could typically be improved with the help of smart home technology. Followed by there is literature review, it has effectively focused on providing some specific and precise theoretical information about the selected study by discussing multiple factors associated with the objectives that the paper has made. The section on the theoretical framework can be considered a major part of the entire literature review, where the paper has discussed multiple factors that are typically associated with the objectives of the research paper. Third chapter of research methodology has specifically helped the paper identify the proper research methods utilized in the process of conducting the study. It can also help the paper select the method of data collection, which has proved to be very effective in completing the entire study systematically.

The next and fourth chapter is analysis and findings can typically be considered one of the most effective sections in the total dissertation as this part has performed a vital role in analysing all the data that have specifically been collected in the review of literature part and identifying some effective results by analysing the collected data.Followed by the fifth chapter as discussion, in this specific section discussion can be very effective in the process of discussing all the major factors there typically associated with the selected topic. This specific section has specifically focused on satisfying the aim and objectives of this study paper.And final chapter is conclusion, in the dissertation, conclusion section has played a major role in summarizing the entire topic in brief and recommending some effective strategies to improve the entire study more precisely and specifically.

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### Chapter 2: Literature Review

### 2.1 Overview

The idea of smart home energy consumption is specifically capable of reducing cost and generating instant changes. The huge demand of electricity has been increasingly rapidly day by day, so the necessity of smart home is also in great demand now a days. So, in this section, the importance of using the smart home automation is explained in detail. Moreover, the significance of machine learning model for predicting the energy consumption is also discussed here.

### 2.2 Theoretical Framework

### 2.2.1 Background of Smart home systems

According to authors Aïvodji, Gambs and Martin, (2019), a house or building that are equipped with the structured and specially designed wiring for enabling the occupants to control remotely or can carry out the program of the automated electronic devices of home through entering a form of single command which can be referred as smart home (Yang, Lee, and Lee, 2018). It is referred to the prior utilization of information technology and computer systems in order to control the features of home appliances like lighting and windows (Marikyan, Papagiannidis and Alamanos, 2019). By the opinion of Popa, et al., (2019), it is understood that the definite system may start with lightning control via remote and go all the way up to microcontrollers based on the networks with the specific varying degrees based on automation as well as intelligence. The home automation has been adopted for the various reasons of security, ease as well as energy efficiency. Yang, Lee, and Lee, (2018) stated that in architectures of smart homes, it is very common that all types of components in networks of home can be controlled by home gateway which acts as a form of service provider for the users. From the viewpoints of Aïvodji, Gambs and Martin, (2019), all types of components and appliances can be defined in the home gateway. A figure is represented below indicating the architecture of smart homes where the gateway of home can control several other appliances of home along with can connect with the user devices by the application of internet. Since some of the home appliances and equipment may work with the use of peer-to-peer setup of network architecture but can be applicable to the home equipment which utilize the similar protocols, a home gateway can be considered to be enabled as the gateway of service and can translate among the various appliances and protocols (Sharif and Tenbergen, 2020).

Diagram

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Figure.1: Architecture of smart home system

(Source: Yang, Lee, and Lee, 2018)

Li et al., (2019) suggested some of the important examples of the smart home equipment as well as home appliances which includes video door phone, door handles, motion sensors, cameras tracking the exterior of homes, audio systems, channel modulators, remote controls, tabletop controllers, keypads etc. The devices and home appliances which connect to the networks of home are considered as receivers as well as the actual means based on controlling system like keypads, remote controls as well as transmitters (Sharif and Tenbergen, 2020). The smart homes hold the potential ability for making life convenient and easier. This promises tremendous benefits for the elderly people and people with disabilities to live alone as it is very easy to monitor and control the automated systems (Aïvodji, Gambs and Martin, 2019).

### 2.2.2 Importance of automation of homes in people’s lives

It is stated by Moniruzzaman et al., (2020) that as the huge demand of electricity has been increasingly rapidly day by day, so the necessity of smart home is also in great demand now a days. The smart home is the upcoming area of the research for providing remote access to constitute the controlling of home appliances or equipment using the concept of intern et of things (Romero et al., 2020). The internet of things-based applications has provided the boom for the old, aged people as well as the person possessing certain disability. It has allowed the user for controlling the device of home automation like bulb; fan etc without making any certain physical sort of connection (Hamdan et al., 2019). It is observed that advancement of the IoT enabled applications has been the state-of art technology between many researchers because of availability of the internet servers. In the opinion of Qolomany et al., (2019), IoT provide the applications for turning the non-smart device that allows the users for accessing such devices through internet. It also converts the home into the smart homes as well as provides a robust method based on controlling home appliances (Moniruzzaman et al., 2020). The security must inclusion of the assistance of installed camera in home so that online tracing is possible.

### 2.2.3 Traditional home energy consumption over smart home energy consumption

According to Jensen et al., (2018), most of the commercials started switching their architecture of energy consumption from traditional to smart homes due to several beneficial properties.

### 2.2.3.1 Traditional home energy consumption

In traditional home architecture, the constant tracking of the energy consumption is not possible with the appliances fitted inside home (Jabbar et al., 2018). In the traditional home architecture, the factor of tracking of the rooms occupied by the users and keeping the temperature according to the desired requirements of them is also not possible (Iqbal et al ., 2018). From the viewpoints of authors Qolomany et al., (2019), it is recognized that it is not possible to get input from the smart phones or android devices in the traditional homes. The issue is that the present energy providers are already struggling to serve the localities they serve. Fossil energy supplies are gradually decreasing, and renewable energy sources are still extremely expensive to install and, by necessity, unstable need (Lotfi & Abdi , 2016).

### 2.2.3.2 Smart home energy consumption

Lee and Choi, (2019) stated the approach of smart home energy consumption specifically provides continuous use of energy within a specific, and data gathered by all the sensors is typically returned back to the central dashboard, which the approach of traditional energy consumption can perform (Romero et al ., 2020). Smart home gives multiple beneficial aspects to the people. It saves huge amount of energy as well as heat as compared to the traditional homes. These smart homes do not restrict the energy consumption, nor can they try for forcing the people in carrying out the activities (Geeng, and Roesner, 2019). They keep proper track of the lifestyle as well as they can be able to determine several ways for not spending much energy when it is required. According to the opinion of Jabbar et al ., (2018), unlike the traditional homes, these smart homes are designed in such a way which can make most available energy. It is claimed by Geeng, and Roesner, (2019) that the first possible way in which the smart homes can save the energy consumption is through heat monitoring. The old thermostats are capable rarely of keeping track properly of the enormous heat in the homes (Sharif and Tenbergen, 2020). In the opinion of Moniruzzaman et al., (2020), the smart homes utilize the multiple sensors for measuring exact temperature as well as possess better form of knowledge based on how to heat it. When it is combined with the system of modern heating, it is easily for the users to possess home warm with the low amount of energy (Chiu et al ., 2021).

The smart homes can save energy through keeping proper track of which of the rooms can be used and at the time for using them. However, the smart homes have the features of controlling the temperature and keeping it as per requirement. The specific feature which is added to the homes is the solar panels (Jensen et al., 2018). The user can place the solar panels on roof as well can connect them to the smart homes. This can also ensure that energy levels associated with home are considered as optimal. In accordance to the opinion of Wadhwani et al ., (2018), it is understood that unlike the traditional homes, the smart homes can make a major difference among the energy which the homes of the user can produce and the sufficient amount of energy purchased by them. A figure is represented below indicating the factor of monitoring the energy consumption in smart homes.

Chart, histogram

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Figure.2: Monitoring of energy graphs in smart homes

(Source: (Stoler, 2019))

In the architecture of smart home automation, it is designed in such a way which brings people as well as their homes in close contact. It goes longer way to conserve energy as well as keeping the lifestyle of the individuals in eco-friendly manner (Jensen et al., 2018). The smart home can provide valuable information or data as well as trying in optimizing what they have currently. It is based on the desired requirements of the uses in providing more number of tools as well as using a better type of environment for utilizing them. Cvitić et al ., (2018) suggested that usage of LED lights are considered as greater way of saving the energy consumption as these lights utilizes much less amount of energy as compared to the regular CFL light bulbs. Therefore it can be said that smart homes can provide data or information more efficiently as well as they can try in optimizing what aspects they have currently (Hamdan et al ., 2019).

### 2.2.4 Characteristics of IoT in smart homes

The internet of things revolves around the advanced machine to machine communication and this definite technology can make everything from the seaports to the smart streetlights. In this opinion of Yang, Lee, and Lee, (2018), this specific value depends on the intersection based on gathering the data or information along with analysing it. Devices that include electronics, software, sensors, as well as connection can be found in a wide variety of forms. (Paul, Ganesh, and Sunitha, 2018). With the guidance of internet of things, such objects can obtain as well as exchange data or information (Qolomany et al., 2019). With the appropriate arrival of the mobile devices like laptops, tablets and smart phones, a new era of the interactive and smart sharing of the information. By the views of Cvitić et al., (2018), IoT is regarded to connect device to sources of internet. For example, the user can determine the smart technology in the smart appliances such as wearable, automobiles as well as mobile devices. The IoT emergence occurred when devices-initiated functioning in a smart way as well as are brimmed with the intelligence for enhancing the interaction with the other type of devices (Iqbal et al., 2018). It is considered as massive impact and it can possess deep impact on the specific lives of average person. A smart home is considered as most searched associated features of IoT on web (Chiu et al., 2021). The cost based on owning a house is of greatest expense in the life of person and the smart home can save huge amount of energy, money as well as time.

In the opinion of Park, Oh and Lee, (2019), a house can be referred to as smart when it holds a range of the smart devices which the user can control remotely through setting them the possible way, they like in authorizing the maintenance of house. The internet of things provides all the digital devices an access to internet that broadens the specific possibilities associated with such networks of home. Pal et al., (2019) stated that the applications based on the investment of things can allow the user in connecting the devices with each other as well as letting the user to communicate without the specific participation. Moreover, IoT significantly improves the possible way in which the user can control as well as monitor all the several processes which are taking place at home (Sivanathan et al., 2018). With the help of IoT enabled devices, the smart fridge can be able to notify whether the yoghurts are spoiled in two or three days as represented in the below figure.4. In usual days, the application of IoT collects the various amount of data or information regarding the possible way the household can work process as well as indicates the significant insights (Wadhwani et al., 2018).

Diagram, icon

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Figure.3: IoT-enabled devices used in smart homes

(Source: Park, Oh and Lee, 2019)

According to the research of Pal et al., (2019), the encompassment of artificial intelligence holds the capability of connecting the multiple internets of things enabled devices which when coupled with the superior processing as well as learning abilities, it can be used for implementing the human behaviour (Abdulla et al., 2020). The artificial intelligence powered devices of smart homes may interact with one another along with acquire new form of data which guides in learning the human habits. The data collected is utilized for predicting behaviour associated with the users along with developing the situational awareness that can understand the user preferences as well as transform the parameters accordingly (Park, Oh and Lee, 2019).

Apart from this, it is also suggested by Shin, Park, and Lee, (2018) that the service of artificial intelligence is used to control the smart devices with the feature of voice control consisting of digital artificial intelligence enabled devices like Alexa, Google Assistant and Siri. From the viewpoints of Park, Oh and Lee, (2019), the advanced security of home systems is possibly controlled through using the voice commands. Many researchers have focused on the aspect of bringing the innovation in the definite field of the voice recognition technology which can add value to the devices based on voice control (Abdulla et al., 2020). The latest advancements in the automation systems of home may enable the owners for gaining the probable access to the channel surfing as well as can control the Bluetooth speakers (Kim, Bae, and An, 2020). The emergence based on feature of voice assistant can raise the security concerns and some of the researchers can be able to manage and hack the smart digital devices.

### 2.2.5 Prediction of energy consumption using machine learning model

Based on the viewpoints of Pham et al., (2020), it is realized that the aspect of matching energy consumption with the right appropriate level of the supply is critical as excess supply of energy might not be stored unless they are converted into some other forms. This can also incur the additional resources and costs. At the similar time, the process of underestimating the consumption of energy can be fatal with the overloading of excess demand as well as can cause blackouts (Shin, Park, and Lee, 2018). There exit certain tangible benefits in monitoring closely the consumption of energy associated with buildings, they can be either office, household to commercial uses. In the opinion of Seyedzadeh et al., (2019) with advent of the machine learning algorithm, the process of predicting accurately the consumption of future energy has become possible increasingly. The accurate predictions offer two folded benefits where at first, the managers can gain the key insights into the several factors which affect energy demand of smart houses or buildings (Zhang, and Gong, 2020). They also provide several opportunities for addressing them as well as improving the energy efficiency. Secondly, the user can forecast benchmark for singling out high and low consumption of energy along with alerting the managers to the faults within building.

According to Pham et al., (2020), prediction refers to specific algorithm output after it is trained on historical datasets and can be applied to the new form of data when they forecast probability of a specific outcome. The algorithm can generate the reasonable hypotheses based on unknown variable for each definite record in new form of data or information which can also allow the user to build a machine learning model for identifying what amount of value is appropriate for the prediction process. The model predictions of machine learning allow the businesses for making high accurate and desirable guess as based on the likely outcomes (Pham et al., 2020). It can provide the business organization with specific insights which can result in the tangible value of business. The implementation and development of the energy efficient technologies provides environmental benefits such as reduced wastage, less harmful emissions, economic benefits from the reduced form of energy as well as resource usage and improved systems of recycling (Chou, and Tran, 2018). For being on proper track of more than one sustainability goals, this requires adequate planning for government, private utility of the organizations as well as policy makers. The machine learning algorithm for predicting energy are used for determining appropriate factors based on the global demand of future sources of global energy. Shin, Park, and Lee, (2018) claimed that the modern techniques of the machine learning are working together with the classified approach such as regression, decision trees and many other models in order to predict better future.

### 2.2.6 Analysing Light GBM Machine Learning Algorithm

According to the statement of Li, Xu and Liu, (2022) Light GBM can typically be considered the short form of Light Gradient Boosting Machine, which is one kind of open and free source distributed slope boosting structure for machine learning that is specifically developed by Microsoft (Minastireanu, and Mesnita, 2019). This specific algorithm is typically based on the algorithms of the decision tree and utilized for several kinds of jobs such as classification, ranking, and more. This specific algorithm has proved to be very effective in the process of predicting energy consumptions within home environment (Cai et al., 2021). The specific algorithm of Light GBM can specifically performs an important role in extending the algorithms of gradient boosting by applying a special kind of automating feature selection and aiming at emphasizing multiple examples with the larger gradients. Alternately Zhang, and Gong, (2020) stated that Light GBM has specifically become a specific de facto algorithm for the competition of machine learning in the period of performing with tabular information for the classification and regression tasks of predictive modelling. Light GBM can typically be downloaded as a separate library, and the model of Light GBM can typically be developed utilizing the API of scikit-learn. In the very first step, the Light GBM library is typically needed to be installed. According to the viewpoint of Cai et al., (2021), this process can typically be achieved with the help of utilizing the package manager of pip python on most of the platforms. After installing the Light GBM library, it is very easy to process the other steps that are typically required in the process of predicting energy consumption (Xia et al., 2019). The library of Light GBM specifically has its own specific custom API, although the method will especially be utilized via the classes of the scikit-learn wrapper, where the two major examples are LGB Classifier and LGB Regressor (Shaker et al., 2021). This effectively plays an important role in allowing the users to utilize the full set of tools from the library of machine learning to arrange data and estimate the models.

In the opinion of Zeng et al., (2019), Light GBM is referred as the framework of gradient boosting that is relay on the decision trees for increasing model efficiency as well as can reduce the usage of memory. This utilizes the two major techniques. The Gradient-based one side sampling as well as exclusive feature bundling that fulfils limitations associated with the histogram algorithm which is used primarily in the gradient-based decision tree algorithm (Cai et al., 2021). Both the techniques are comprised together for making the model can work efficiently along with providing it cutting edge over certain frameworks (Gao et al., 2021). The various instances of data possess varied roles in computation of the gain of data or information. The specific instances consisting of larger gradients can contribute more amount of data or information to data gain. Gradient-based One Side Sampling (GOSS) is considered for keeping the instances with larger number of gradients as well as drop randomly the instances consisting of smaller gradients for retaining information accuracy and estimation gain (Zeng et al., 2019). This treatment may lead to more accuracy of the gain data or information as compared to the uniform state of random sampling with the similar target of rate of sampling especially when it is considered that the value based on data gain possess large wide range (Malki, Atlam, and Gad, 2022).

From the opinion of Zhang, and Gong, (2020) it is understood that Light GBM has the ability of splitting tree leaf-wise as they are opposed for other boosting algorithms which grow trees in level wise. This can select leaf with the maximum loss of delta for growing. It is regarded that since leaf is fixed and the leaf-wise machine learning algorithm possess low rate of loss when compared to level-wise machine learning algorithm (Malki, Atlam, and Gad, 2022). The growth of the leaf wise model can increase the model complexity as well as can lead to the aspect of over fitting in the small number of datasets as represented in the below figure

Chart

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Figure.4: Leaf-wise Machine learning algorithm

(Source: Zeng et al., 2019)

According to the views of Zhang, and Gong, (2020) the specific power of Light GBM machine learning algorithm may not be taken lightly as the algorithm Light GBM is efficient as well as distributed which uses the tree-based aspect of learning. Some of the advantageous features of the Light GBM algorithm includes better rate of accuracy, faster speed of training as well as enhances the higher efficiency (Ju et al., 2019). It can also support GPU learning and possess the ability to handle large scale information. The parameters which are used in this specific algorithm for getting faster speed of this machine learning algorithm includes max\_bin, feature\_fraction, bagging\_freq, bagging\_fraction, parallel learning etc (Malki, Atlam, and Gad, 2022). Moreover, it can also be stated that this specific framework can utilize leaf-wise growth of algorithm which is mentioned earlier and is considered as unique among the other models using the depth-wise growth. The application of this machine learning model involves multi-classification, cross-entropy, regression utilizing L2 loss, binary classification utilizing objective log loss function (Zhang, and Gong, 2020). This model can be used to predict the energy consumption and helps to determine if the energy efficiency used in an equipment is (Tang et al., 2021).

### 2.3 Literature Gap

In this study, it has been focused the background and significance of smart home systems used in recent times by many people across the world. The beneficial features of using the smart home automation system are analysed thoroughly in this section. The home automation has been adopted for the various reasons of security, ease as well as energy efficiency. The devices and home appliances which connect to the networks of home are considered as receivers as well as the actual means based on controlling system like keypads, remote controls as well as transmitters. However, the drawbacks and the faults of using the smart homes are not defined in these studies considering energy consumption. Moreover, the focus of this study is on smart home equipment but has not taken into consideration the other advanced technologies used by people such as smart economy, smart environment and many more. In addition, the benefits of using machine learning model in predicting the energy consumption is also explained in this part of literature.

### 2.4 Aim and Research Question:

This research paper specifically aims to analyse the effectiveness of smart home energy consumption compared to traditional energy consumption. According to the formed aim, this specific research paper has also identifies some an effective research question, which can be very effective in helping the research paper to identify all the major factors associated with the topic of the effectiveness of Smart home technology by limiting the research area (Masor & Harder, 2020) The research question is:

* Why smart homes architecture is more efficient than traditional homes in terms of energy consumption during the year 2016 to 2021 in UK?

### 2.5 Objectives:

Based on above specific aim, this paper has also formed some effective objectives, which help the study to be conducted in a systematic manner. The objectives are:

* To identify the difference between traditional and smart home energy consumption
* To determine the factors that have an impact on smart home energy consumption
* To design a model/models for smart home appliances considering energy consumption
* To estimate the performance of the model/s
* To predict the complete energy consumption of smart home appliances

### 2.6 Conceptual Framework

Multi-functionality

Adaptability

Interactivity

Energy Efficiency

Automation

Figure 5: Conceptual Framework

(Source: By author)

Smart homes are considered as the specific homes consisting of the technological advanced systems for enabling the automation of domestic task, easier level of communication as well as providing high security. In the above figure, it can be seen about the beneficial features or factors which are offered by the smart homes to the people in daily life (Wadhwani et al., 2018). The factors which are provided by the smart home technologies as an advantage to the environment are adaptability, multi-functionality, interactivity, automation as well as energy efficiency. It is significant in today's world to save energy as it is the most demanded resources across the world, so smart homes are considered as the effective advanced technology which must be implemented in very homes and save huge amount of energy.

### 2.7 Summary

In this chapter of literature review, it is mentioned that the demand for reducing energy costs is growing every day with the rising number of constructions and businesses in this current generation. The opinions of several authors and researchers are analysed and it is found that the approach of smart home energy consumption specifically provides continuous use of energy within a specific, and data gathered by all the sensors is typically returned to the central dashboard, which the approach of traditional energy consumption can perform. The background and significance of using the smart home automation is explained in this part. the concept of smart home energy consumption is specifically capable of reducing cost and generating instant changes. Moreover, the traditional technologies used in home are also compared with the smart home technologies.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Author Name** | **Factor** | **Method** | **Future Scope** | **Limitation** | **Year** | **Description** |
| Sebastian Petrick, Katrin Rehdanz and Richard S. J. To | Temperature | Tensor Flow | Testing of network | Only one model is used | 2010 | The study provides the temperature has significant impact on the energy consumption. In the winter season the energy consumption of the residential area is significantly low. |
| Strielkowski, W., Kovaleva, O. and Efimtseva, T., | Wind | CNN | New generation technology can be used | Accuracy is low | 2022 | The digital technology provides a higher percentage of variables of renewable energy for aligning the energy demand with wind power |
| Strielkowski, W., Kovaleva, O. and Efimtseva, T., | Humidity | Tensor flow | Updated algorithms can be used | Lack of comparing of accuracy | 2022 | The sensors and monitoring system controls the environmental factors such as humidity |
| Nyborg, S. and Røpke, I. | Pressure | LSTM | Need more data visualization | Improper presentation of model | 2011 | The smart home devices can reduce the pressure of energy consumption |
| Mazzeo, D. and Kontoleon, K.J., | Temperature | DAE | Need to improve accuracy | Low accuracy | 2020 | The average household consumption of low temperature and high temperature is compared |
| Guan, H., Beecham, S., Xu, H. and Ingleton, G | Humidity | CNN | Lack of dataset information | Can be used multiple algorithms | 2017 | The meteorological factors can influence energy consumption such as humidity |

Table.1: Information of survey in tabular form

(Source: Created by author)

### Chapter 3: Research Methodology

### 3.1 Overview

Detailed information about the appropriate methods of research that can help the project to provide the effective outcome is mentioned in this section. In this section, information the research methodologies include research philosophies, research strategy, research approach, data collection, data analysis techniques are described. The ARIMA models, Light GBM and LSTM are utilized in this study for predicting the energy consumption of smart homes.

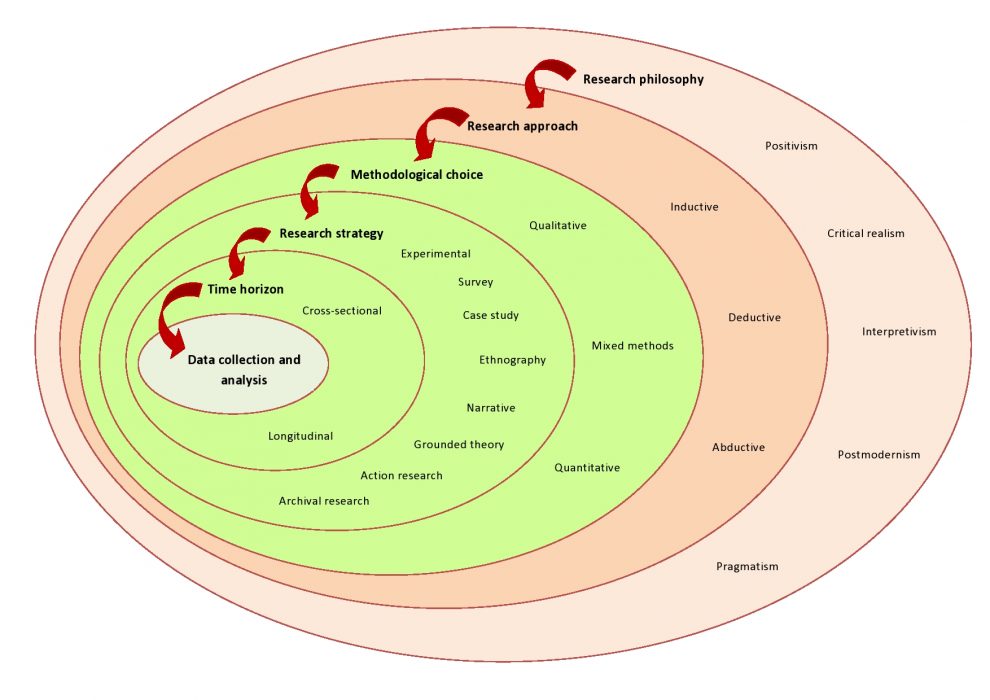


Figure 6: Research Onion

(Source: (Lotfi & Abdi , 2016))

### 3.2 Research Methodology

### 3.2.1 Research Philosophy

Research philosophy is regarded as a specific viewpoint on the possible way where the significant data regarding a single phenomenon must be collected, analysed as well as utilized (Žukauskas, Vveinhardt and Andriukaitienė, 2018). The research philosophy is related to the knowledge, assumption, and nature of research study. This deals with certain way based on developing knowledge (Snyder, 2019). This specific matter requires for being addressed as the researchers can possess various specific assumptions regarding nature based on truth as well as knowledge along with this philosophy can assist the researchers for understanding their specific assumptions. It is considered that although the idea based on knowledge creation can appear for being profound, the research scholars can remain engaged in the task of creating knowledge as a specific part of completing the dissertation study (Rashid, 2021). There are four types of philosophies existing in the research philosophy section which includes pragmatism, positivism, realism and interpretivism. These philosophers reflect significant assumptions of the research scholar, and such assumptions can serve as the definite base for research strategy (Pandey and Pandey, 2021). For this context of the study based on enhancement of smart home architecture, out of the four types of philosophies, interpretivism can be selected as appropriate approach of research philosophies. The interpretivism philosophy is generally based on the specific principle that says the researcher can play a specific role in observing the social world (Snyder, 2019). The main reason behind the selection of research philosophy is that it provides data or significant according to reality and seeks to understate the entire world by directly experiencing phenomena (Žukauskas, Vveinhardt and Andriukaitienė, 2018). With the help of interpretivism philosophy, it can be ensured that data or information provided in the study is valid as well as very close to truth. For this project, the interpretivism is utilized.

### 3.2.2 Research Strategy

Research strategy is considered as whole plan to conduct research study. The strategy guides the research scholar in executing, planning as well as monitoring study. It is a step-by-step plan that gives ideas for what to do a specific direction to the thought process of researchers. Generally, research strategy is defined as systematic process regarding how possible way research can be conducted in order to solve inquiry issues (Newman and Gough, 2020). This methodology helps to introduce major components associated with the research project like area of research topic, perspective of research and its focus. There are various strategies available of conducting a research project such as Experimental, survey, case study, ethnography, narrative, grounded theory, action research, and archival research (Rong et al., 2020). Among these research strategies, the research scholar can select experimental strategy as effective to carry out this study based on smart home automation architecture. This is because, in the present study researcher is working on the dataset which is having dependent and independent variable. According to (ABDELHAKIM & BADR, 2021), research study is an experiments of two different variables and they are nothing but dependent and independent variables and remaining are get controlled.

### 3.2.3 Research Approach

The research approach is defined as the procedure or plan which generally comprises of various steps based on broad assumptions to the detailed methods associated with collection of data, analysing it as well as interpreting it (Roy and Uekusa, 2020). So, it can be said that this method of research approach is based on nature of problems of research for addressing them. The research approach is classified further in three categories as deductive approach, abductive approach, and inductive approach (Rinjit, 2020). For this context of research work based on enhancement of smart home automation architecture, the deductive approach can be chosen as effective. The main reason for selecting this approach is that deductive approach prefers abundance sources of data or information and contains less time to complete the task. As per the (ABDELHAKIM & BADR, 2021), deductive approach is suitable for the conceptual as well as theoretical type of development considering the practical results. The deductive approach explores a phenomenon or known theory as well as tests if the theory can be stated as valid in the mentioned circumstances.

### 3.2.4 Data Collection Method

The data collection is defined as the associated process based on gathering information from all types of relevant sources to determine the answers to research issues along with tests the hypothesis. This method of data collection helps in evaluating the results or outcomes which can help the project to achieve success. The method of data collection can be classified into primary and secondary data collection (Ngozwana, 2018). For this study based on smart home automation architecture with using machine learning algorithms, the secondary data collection method can be preferred by the researcher. Secondary data is referred as specific data type which are published in newspaper, books, journals, internet sites, online portals etc. There exits lots of data in these secondary sources regarding the area of research work. So, application of secondary data collection method performs an important role in increasing levels validity and reliability for research. Moreover, this method of secondary data collection can also provide a definite range of the beneficial advantages like saving time consumption, expenses as well as efforts (Sileyew, 2019). Therefore, it can be stated that secondary collection of data can provide beneficial advantages to this study.

### 3.2.5 Data Analysis method

Appropriate techniques of data analysis can guide the research individuals in obtaining genuine outcomes. For analysing and examining collected data by secondary means, the research individuals can utilize various techniques to analyse data accurately. In this study, quantitative methods are selected that can aid in gathering data from secondary sources. The research individual can apply MS word to analyse the quantitative data (Newman and Gough, 2020). The quantitative data has been shown in charts, graphs, tables, and bar diagrams in a descriptive way. The statistical tool could be used by a researcher in order to get better results.

### 3.3 Analysis of Machine Learning Algorithms

For this study, three deep learning algorithms known as Light GBM, ARIMA, and LSTM are selected. They are compared among each other based upon their features and determining which algorithm is best suited for this research study (Bahrami and Forouzanfar, 2022). Light GBM is considered as fast, distributed, and high performance boosting gradient framework that is associated with the algorithm of a decision tree, which is utilized for ranking, classification as well as executing other task of deep learning (Ju et al., 2019). As, it is dependent on decision tree algorithm, it can split leaf-wise tree fits best whereas other boosting algorithm can split tree by level wise to depth wise instead of leaf-wise. This leaf-wise deep learning algorithm can help reduce more amount of loss as compared to level-wise machine learning algorithm and results in generating better form of accuracy that can be achieved through any present boosting algorithms (Bahrami and Forouzanfar, 2022). The leaf-wise method of splitting by this algorithm can lead to increased complexity as well as can lead to the scope of over-fitting (Cai et al., 2021). There is a way to get around this problem. You can set another range of parameters for how far down the method of splitting can be used. Moreover, light GBM can utilize histogram related with algorithm which buckets the continuous featuring values and converting into discrete bins fastening training procedure (Sun, Liu and Sima, 2020). This machine learning algorithm replaces the continuous values to the discrete bins that results in enhancing lower usage of memory.

On the other hand, another machine learning algorithm which is analysed in this study is ARIMA model. ARIMA (Autoregressive Integrated Moving Average) is considered as a form of regression analysis indicating specific strength based on dependent variable which is associated with several variable changes (Satrio et al., 2021). The main objective of ARIMA model is used for predicting movement of the future of time series by examining variation that exists among specific values in the series instead of utilizing actual type of values (Borucka, 2018). ARIMA models can be applied in the cases where the significant data representing evidence of non-stationary. Moreover, non-stationary data or information is transformed into creating stationary data under this model. This model is utilized for demand forecasting such as determining future scope of the demands in food manufacturing (Rahman, Alam and Rahman, 2019). In addition, ARIMA models can be utilized for predicting future price of stocks which are dependent on past prices. Also, it helps in analysing real-time consumption of electrical energy of smart homes.

In addition, another deep learning algorithm are also analysed in this particular study based on enhancement of a smart home automation architecture is LSTM algorithm (Satrio et al., 2021). The Long Short-term Memory networks are defined as extension of the recurrent neural form of networks which is introduced majorly in order it handle situations where the recurrent neural form of networks can fail. LSTM network works generally on present input variables through considering previous feedback output as well as stores memory for shorter time (Tax, 2018). It is considered that unlike the standard feed forward neural connections, the long short-term memory possesses feedback connections. This deep learning algorithm not only processes a single point of data like images but can also include the overall data sequences. Moreover, this deep learning algorithm is applicable to execute such tasks like handwriting recognition and speech recognition (Chung and Shin, 2018). LSTM networks are regarded to be suited well to processing, classifying as well as generating predictions which are dependent on the time-series data or information as since there exist lags of the unknown duration among the significant events in time series (Mekruksavanich, and Jitpattanakul, 2021).

All these three algorithms are compared among each depending on their characteristic features. Based on the analysis, it can be said that light GBM algorithm is the effective one because it provides faster speed of training as well as provides outcomes with huger level of efficiency. Moreover, lower usage of memory is also possible with light GBM model as it replaces the continuous values to the discrete bins.

### 3.4 Data cleansing

Data cleaning is considered as one of the significant parts of machine learning. This plays an important part in creating a model. It is defined as a specific process based on identifying and removing an incomplete, incorrect, irrelevant, inaccurate or missing segment of data along with modifying, deleting and replacing them based on the requirements (Lyan et al., 2022). The process of data cleaning is regarded as foundational element of data science. Data is most valuable thing for machine learning and analytics. In this study context, this data cleaning process includes removing unwanted or unnecessary observations (Hara, Nitanda, and Maehara, 2019). Deleting redundant, irrelevant, or duplicate values from the specific dataset comes under this technique. The duplicate observations arise frequently during the process of data collection. The irrelevant observations are considered as those which fit the desired issue faced by the researchers.

The main importance of deleting these unnecessary observations from the dataset is that it alters the efficiency of analysing data by greater extent because the data or information keeps on repeating and can add towards the correct side. The irrelevant observations are considered as specific type of data or information which is made of no usage along with may be removed directly (Chung and Shin, 2018). The data cleansing process also includes the method of fixing structural errors. The errors which arise at the time of measurement, transferring of data or several other similar types of situations are referred as structural errors (Lyan et al., 2022). The structural errors also includes typos in the specific name of features, similar attribute with variant name, mislabelled class, etc. are also necessary to be removed in order to obtain the profitable outcomes (Neira-Rodado et al., 2020).

Graphical user interface, application

Description automatically generatedFigure 7: Data Cleaning

### 3.5 Summary

In this study, appropriate as well as effective methods of research are selected to gain profitable results. The research methodology is analysed effectively by describing all the research methods such as research philosophies, strategies, approach, data collection method and data analysis method. A detailed discussion upon all these methods is carried out in this study along with predicting the effective methods to execute the task efficiently. In addition, several models that can learn from both machine learning and deep learning are out there that can be analysed based on their features.

### 

### Chapter 4: Implementation Method

### 4.1 Overview

Deep learning is a part of machine learning which helps in making systems that improve and learn by themselves automatically by specifically being programmed. To achieve the exact requirements and the result considering the methodology which is used in above section we need to follow the appropriate techniques. Here we are using CRISP-DM process model for achieving the study goal after analysing the methodology model. The systems are expected for determining the specific patterns in collection of data as well as utilize them for making the critical decisions for them. Machine learning makes the system to act and think like the humans along with representing the human intelligence power.

### 4.2 Implementation steps

The implementation steps which are necessary to carry out the machine learning algorithms considering the CRISP-DM process model are as follow:

Diagram

Description automatically generated

Figure 8: CRISP-DM Model

(Source: (Locke, 2017))

**Stage 1: Business Understanding:** The first step in any project is to figure out what the project's goals and needs are from a business point of view(Wirth & Hipp, 2000). After identifying business plan and the requirements of achieving the smart homes energy consumption, researcher figured out objectives which fulfil the business plan. After analysing the problem, next is transforming requirements into data mining proposed solution (Nadali & Kakhky, 2021).

**Stage 2: Data Understanding:** The next step of the CRISP-DM process model is data understanding. And data understanding consists of the four phases, collect initial data, describe data, explore data, and verify quality data (Wirth & Hipp, 2000). In the present studies, it has been considered that objectives and the requirement for the studies helps to collect the data. Data has been collected from Kaggle for this study (Anttal, 2016)[Appendix C] To make it more tangible, the user guide describes the data description task in terms of statistical analysis and defining qualities and their collations (Schröer & Kruse, 2020). Business understanding and data understanding is having two-way connection.

**Stage 3 : Data Preparation:** Data preparation stage is having six different phases in it, they are as follow: data set, select data, clean data, construct data, integrate data, and format data (Wirth & Hipp, 2000). According to the (Wirth & Hipp, 2000), data preparation process can be performed many times on the dataset and in any order. In this study, data preparation has been done on the dataset to prepare dataset in such a way to make it ready for modelling tools. In present study, the dataset is having huge number of records and among them some are of not useful for the study. Therefore, in data preparation stage, data cleaning has been done and reformatted data achieved.

**Stage 4: Modelling:** modelling consists of four phases, and they are as follow: select modelling technique, generate test design, build model, and assess model (Wirth & Hipp, 2000). modelling and data preparation have a close link among them. There can be multiple data techniques for the same data mining issues.

The accuracy of training the dataset or validating dataset is considered as critical to precise the model. In addition, the model training is defined as the specified process associated with feeding a machine learning algorithm such as Light GBM with significant data or information necessary for a project to guide the use in identifying as well as learning the food values for all types of attributes included in the research project (Alaa and van der Schaar, 2018). It is considered that training is considered as most important in the machine learning process. In the process of training the model, the user can pass prepared information to the selected model of machine learning with an aim to determine the certain patterns as well as create predictions. This results in scope of model learning from relevant data so that sets of tasks can be accomplished (Leroux, 2019). Over passing time with training model, the machine learning model gets accurate at predicting. The performance of the model at the time of training can eventually determine how properly it can work and put it into application for end-users.

**Stage 5: Evaluation:** As per the requirements and objectives there can be one or more models, we can build to achieve the goal (Nadali & Kakhky, 2021). Before going for the last step of the deployment one should test the evaluation for the models. For this study, three models have been constructed to achieve the business objectives. Determine the key objectives to understand if there is any crucial business issue which is not considered during the process (Wirth & Hipp, 2000). Every model of machine learning holds various parameters which can be set. This process of parameter training possesses big impact on the task of model training as it can relate to the training time, resource requirements of infrastructure, model accuracy and model convergence. The significant parameters used in Light GBM model arenum\_leaves, num\_iterations, Small max\_bin, max\_depth, sub\_feature, min\_data\_in\_leaf etc.

**Stage 6: Deployment:** Basically, this step is the last step of the project and end of the process. Deployment stage consists of four phases, and they are as follows: plan deployment, plan monitoring and maintenance, produce final report and review project (Wirth & Hipp, 2000). Once the model development and testing done properly, the business idea is ready to get deploy for the client. Here in this study, all models are tested along with their criteria and the conditions to get the result. According to the evaluation of the models the final report gets generated which is nothing but the final deliverables as per the business objectives (Nadali & Kakhky, 2021). Monitoring and maintenance are equally important for the deployment as it gives the clarification to the process. And in the end, it is mandatory to review the project as considering the business requirements (Schröer & Kruse, 2020).

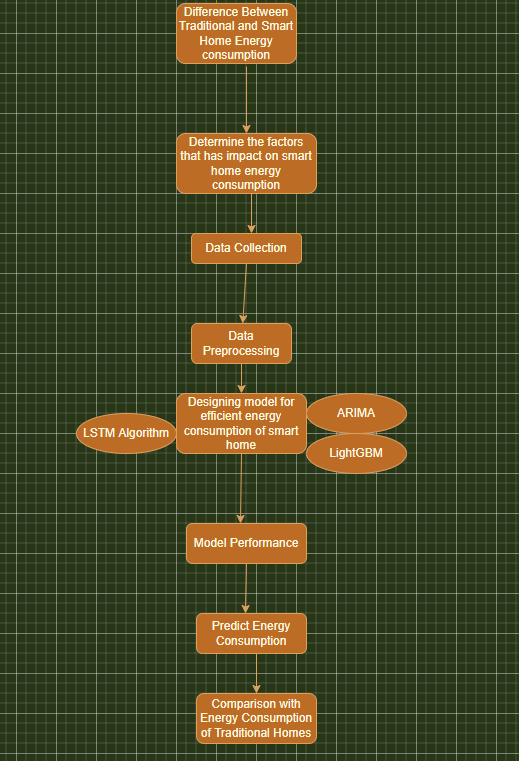


Figure 9: Flow Chart

(Source: Created by Author)

### 4.3 Summary

In this study, the different stages of implementing the machine learning algorithm to carry out the project based on the enhancement of smart home automation architecture. The first stage of the implementation method of the machine learning model is data collection. The data or information necessary for carrying out this study are collected from valid or reliable sources and impact positively towards good quality of data (Alaa and van der Schaar, 2018). It is mentioned in this section of the study that the data quality which the user feeds into the machine can determine the accuracy of the model. The next stage of this implementation method is data preparation. It is also mentioned in the study that data preparation also includes cleaning data for removing unnecessary data, missing values, columns, rows, data type conversions, and duplicate values (Ngiam, and Khor, 2019). The third stage of the implementation method is model selection.

An appropriate model is chosen by the research individual depending on the requirements of the research project. The next stages are training and evaluating model. Training is regarded as the primary step in the machine learning, which leads to a working model and is possible to test, validate as well as deployed. On the other hand, testing the model is regarded as a definite process where performance associated with a fully trained model can be evaluated on the testing set (You et al., 2019).

Diagram

Description automatically generated

Figure 10: Use-Case Diagram

(Source: Created by Author)

### 5.0 Analysis and Findings

### 5.1 Overview

In this section, the analysis is executed with the help of a deep learning model that provides the overall energy consumption of the smart home. Apart from this, the comparison is done based on the energy consumption between the traditional home and smart home. The pre-processing of the selected dataset is done with the help of Keras. The utilities of the pre-processing in Keras are found at tf.keras.preprocessing helps to define the object within the raw data that can be used to train this deep learning model. The selected dataset is cleaned with the help of the isnull() function. This function returns the data frame object in which all the data is replaced with true for the null values and false for the not null values. For the analysis of the data, LSTM, LGB, and ARIMA algorithms have been used that help to provide the prediction of the energy consumption over a specific time. Apart from this, the selected dataset also considers the weather condition that helps to specify the energy consumption based on the weather as well.

### 5.2 Data Visualization

Data visualization is the process that helps to provide a better understanding of the data with the help of the graphical representation. This process helps to provide insight information about the dataset in the form of graphs and charts. Matplotlib and Seaborn libraries are used for the data visualization for this dataset. These libraries are in-built module that helps to plot different graphs. Matplotlib is used for the embedded graphs whereas Seaborn is used for the statistical graphs. Matplotlib is utilized for basic graph plotting such as pie charts, bar graphs, etc and this method is used for the dataset and arrays. On the other hand, the Seaborn library is worked on the entire dataset which is considered more organized and functional compared to other graphs. This method has in-built themes that are essential for the statistical analysis of the dataset. [Appendix C]

The correlation provides the relationship between the dependent and the independent variables of the selected dataset. The relationship can be negative and positive. The neural relationship shows no relationship among the variables that is denoted as zero.

Chart, timeline

Description automatically generated

Figure 11: Correlation Analysis of Appliances

(Source: By Author)

From the above graph, the home office has a positive relationship with the dishwasher with a value of 0.066, and the dishwasher has a positive relationship with the fridge with a value of 0.034. On the other hand, a negative correlation is seen between the dishwasher and wine cellar, and the value is -0.0046. The garage door has a negative relationship with the dishwasher with the amount of -0.009. The barn has a positive value of 0.0069 in terms of the relationship with the dishwasher. In the case of a well, the value is 0.0083 and in the case of a microwave, the amount is -0.0012. The living room has a value of 0.00061 and the furnace has the amount of -0.0042. Lastly, the kitchen has the amount of 0.0033. In the case of the home office, the value of the relationship with the dishwasher is 0.0066 and with the fridge is 0.035. The value of the wine cellar is 0.0039 and the value of the garage door is -0.014. Apart from this, the value of the barn is -0.038 and the value of the well are -0.0065. The amount of microwave is -0.0079 and the amount in the living room is -0.052. The value of the furnace and kitchen are -0.018 and 0.0075. In the case of the fridge, the wine cellar amount is 0.076 and the barn amount is -0.0024. The well amount is 0.011 and the microwave value is 0.026. The value of the living room is 0.054. The furnace and kitchen have the amount of -0.018 and 0.0075. The wine cellar has a positive value with well and a negative value with the furnace. The garage door has a negative value with the dishwasher, home office, and microwave. The barn has the negative value with the home office and well has the negative value with this variable. The living room has a negative value with the barn and the furnace has a negative amount with the fridge, wine cellar, garage door, and microwave. Lastly, the kitchen has a negative amount with barn. Based on the above analysis, all the values have a relationship in both positive and negative manner. Thus, all the variables have a correlation with the other variables. Therefore, these variables are essential for the prediction of energy consumption.

Chart

Description automatically generated

Figure 12: Correlation of Weather

(Source: By Author)

The above correlation matrix shows the relationship between the variables of the weather which are taken into consideration for the prediction. From the above correlation, the temperature has a positive value with the apparent temperatures with the value of 0.99. The temperature has a negative relationship with the humidity with the amount of -0.09. In the case of visibility, the value shows the positive amount which is 0.11 and the visibility amount is -0.19. The value of wind speed is -0.059 and the intensity value is 0.04. The dew point amount is 0.89. In the case of apparent temperature, the humidity has a negative value which is -0.45 and the pressure has also a negative value which is -0.17. On the other hand, visibility and dew point has a positive value which is 0.044 and 0.9. In the case of humidity, the temperature has a negative value and visibility has also a negative value. The dew point has a positive relationship with the humidity. In the case of visibility, the dew point and humidity have a negative amount with the values of -0.51 and -0.091. In pressure, the temperature has a negative implication with a value of -0.19. This variable has a positive relationship with visibility. The wind speed has a negative relationship with pressure and a positive relationship with visibility. Lastly, the dew point has a negative relationship with the pressure and a positive relationship with the visibility. Based on the above, all variables of the weather are correlated to each other in both positive and negative manner.

Graphical user interface

Description automatically generated with medium confidence

Figure 13: Temperature Value over the Time Period

(Source: By Author)

From the above graph, the temperature shows the upward direction compared to the base time. The temperature has increased over the past few months which are one of the essential aspects for predicting the energy consumption. In this diagram the output is so noisy. The lowest energy consumption is shown in January month whereas the highest value is shown in the July month.

Chart

Description automatically generated

Figure 14: Mean value of Temperature

(Source: By Author)

The above figure shows the average temperature value over the past few months for better understand. Similarly, the highest mean value is shown in the month of July to September whereas the lowest value is shown in the month of January. The above graph shown has the increasing the time over the time. Thus, temperature value has increased in the present time compared to past time.

Graphical user interface, text, application, Excel

Description automatically generated

Figure 15: Use and House Overall

(Source: By Author)

The above graph represents the use and the house overall of the energy consumption. As both the columns are having the same output and information, we are deleting one column from data. From the above graph, the value has the increased in the month of July to September. The value has the decreased in the month of October to December. Thus, the graph shows the decreasing trend in the present time compared to the base time. Thus, the in the winter season, the use and the house overall energy consumption is significantly low.

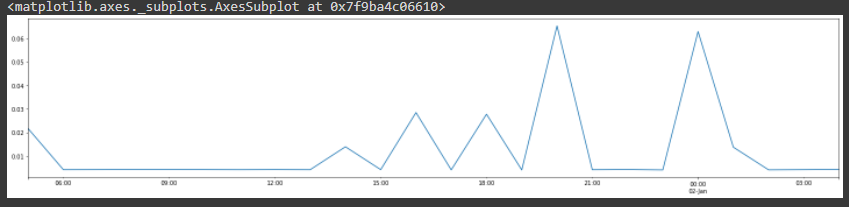


Figure 16: Microwave Energy Consumption

(Source: By Author)

The above figure shows the energy consumption of microwave in hourly time. The highest energy consumption is shown in the evening and nigh time. The graph shows the decreasing value after the night-time to morning time. Thus, the most energy is consumed at the evening to night-time.

Chart, scatter chart

Description automatically generated

Figure 17: Moving Average Value

(Source: By Author)

From the above graph, the rolling mean trend value is shown like the actual values of the energy consumption. The value is shown as the decreasing after the comparison. Thus, the graph has the downward trend in the present. Thus, the moving average of the energy consumption is like the actual value.

Chart, line chart, scatter chart

Description automatically generated

Figure 18: Anomaly Detection

(Source: By Author)

The above graph shows the anomaly of the moving average value. From the above graph, nine anomalies are detected based on the actual value of the energy consumption. These values can affect the model in a negative manner. Thus, these values need to be removed before the prediction.

Chart, line chart

Description automatically generated

Figure 19: Energy Usage Prediction

(Source: By Author)

The above figure shows the prediction value of the energy consumption of the smart home. From the above, without considering the weather factors, the predicted value is not like the actual value of the energy consumption. The highest value is more than 3.0 and the lowest value is less than 0.5. In the case of prediction, the values lie from 0.5 to 1.0. Thus, the prediction value is not accurate.

Graphical user interface, chart

Description automatically generated

Figure 20: Prediction after Considering Weather

(Source: By Author)

The above figure shows the prediction after considering all the factors of weather. From the graph, the predicted value is like the actual value over the past year. The highest actual value is more than 2.5 whereas the highest predicted value is more than 1.5. The lowest value of the prediction is 0.5 and the lowest actual value is less than 0.5. Thus, the accuracy of the prediction has increased after considering all the weather factors.

### 5.3 Model Evaluation

The model evaluation shows the performance of this deep learning model in terms of its accuracy and error value. Initially, the accuracy of the prediction is low compared to the actual value, but after considering the weather, the accuracy has increased significantly, and the predicted value shows the similar result of the actual value.

Chart, line chart

Description automatically generated

Figure 21: Exponential Smoothing

(Source: By Author)

The above graph shows the exponential smoothing of the model. For this process, the alpha value is considered, and two alpha values are taken into the account. The first alpha value is 0.05 that is lies in the centre of the graph. In the case of 0.3, the value shows the similar type of amount of actual value. Thus, the 0.3 value is considered as the alpha value of this model.

Chart, line chart

Description automatically generated

Figure 22: Model Completion

(Source: By Author)

The above graph shows the model evaluation process at the completion of the prediction of 94%. From the above, the predicted value accuracy is 0.9430 and the expected value is 0.935. The error value of the model is 0.179. Thus, the error of the model is significantly that can be seen after the completion. The predicted value is higher than the actual value of the energy consumption.

Chart

Description automatically generated

Figure 23: Progress at 99%

(Source: By Author)

The above graph shows the prediction progress at 99%. From the above, accuracy of the model has increased with the value of 0.9572 and the expected value is 1.369. The error value of the model is 0.076. Based on the above, the error value is significantly low after the completion of 99%. The accuracy of the model has increased which can be determined after the completion value. Thus, the model accuracy has increased in a significant manner after the completion of 99%.

### 5.4 Energy Consumption of Traditional Home

The calculation of the traditional home energy consumption is difficult because several factors can affect the consumption value. The energy efficiency is based on the appliances, temperature of the area that affects the usage of the energy of household. In the traditional home, the energy usage of the consumer is determined by the supplier of the energy in the form of charges of the gas and electricity (Bourazeri and Stumpf, 2018). The suppliers of energy use the prediction of the used energy amount based on the past data. The new generation meters are considered as smart which provide the precise reading of the energy that helps to compare the details of the energy for the prediction. In the traditional home, the energy is used based on the area and the size of the house as well as the number of people living in the house. The energy consumption is divided into three categories such as low, medium and high. The low is considered as the small apartment with the number of people of two. The medium is considered as the household of 3-4 people in the detached house (Nelson and Allen, 2018). The high segment is the number of more than 4 people in a detached house.

|  |  |
| --- | --- |
| **Usage Tier** | **Consumption Value (kW)** |
| Low | 1.8 |
| Medium | 2.9 |
| High | 4.3 |

Table 2: Energy Consumption of Traditional Home

(Source: By Author)

According to the above table, the low tier has the energy consumption amount of 1.8 kW, and the medium has the consumption value of 2.9 kW. On the other hand, the high has the energy consumption amount is 4.3. Thus, high has the highest amount of energy consumption.

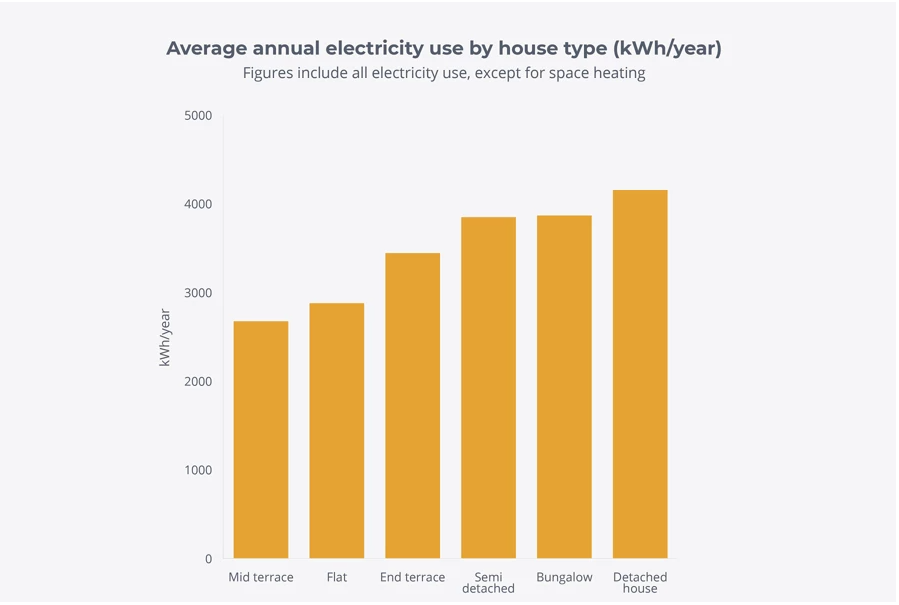


Figure 24: Electricity Usage by House Type

(Source: Lee et al., 2020)

From the above graph, the mid terrace houses have the lowest energy consumption, and the detached house has the highest energy consumption value. This value is based on the number of people living in the house.

Figure 25: Energy Consumption of Traditional Home and Smart Home

(Source: By Author)

Based on the above analysis, the energy consumption of the traditional home is from 1.8 to 4.3 that are significantly high, and the household pays the high amount of bill to the supplier. The supplier has several difficulties to predict the value of the energy consumption. The prediction of the energy consumption with the help of past value is one of the critical barriers.

### 5.5 Summary

From the above section, the deep learning model provides insight information about the smart energy with the help of graphical representation. The accuracy of the model is significantly high, and the prediction value shows the similar amount of the actual value. The smart home energy usage is significantly low compared to the traditional homes.

### Chapter 6: Discussion and Result

According to the analysis, the accuracy of the model is significantly high after considering the weather. Thus, weather is one of the important factors for predicting the smart home energy consumption. On the other hand, in the case of traditional household, the consumption of the energy value is significantly high which is from 1.8 to 4.3. In the smart home, the energy consumption value is 0.5 to 3.5 (Bourazeri and Stumpf, 2018). Thus, the energy consumption of the smart home is significantly low compared to the traditional home. Apart from this, the prediction of energy usage of the traditional home is considered as the one of the complicated processes (Roesch and Günther, 2019). This process only considered the past events which is one of the barriers of the prediction of the traditional home. This model has taken several factors into the consideration before predicting the usage of the energy.

This study describes the energy consumption of smart home automation architecture. A building or house which is equipped with structural designed wiring to enable occupants is that it can be controlled remotely or can be able to carry out a program of automated electric devices of the house by entering a single form of command that is referred to as smart homes. It is discussed in this study that the smart systems can range from the remote control of lightning to the complex system of micro-controller, which is based on services of the network containing specifying degrees. Smart homes make sure that the user can save electric energy as well as helps in reducing the bills of electric and water (Bourazeri and Stumpf, 2018). It is often observed that the light may remain on because of laziness of getting up to turn them off. The smart home can allow the user in turning off the lights as well as several other electronic devices at the time of sleeping and going to bed. It is also mentioned in the study that smart homes allow the user to possess greater control of overall usage of energy in the household. In this research, a background of smart home automation is described, where the architecture of smart homes is explained. Some of the smart home equipment which is used in designing the smart homes are also explained in this study, such as video door phones, door handles, cameras tracking the exterior of homes, channel modulators, remote controls, keypads, audio systems, etc (Maswadi, Ghani, and Hamid, 2020).

It is mentioned in this study that in the architecture of traditional homes, the aspect of tracking rooms which are occupied by users as well as keeping proper track of temperature based on their desired requirement is not possible. However, the smart homes have the features of controlling the temperature and keeping it as per requirement. The main goal of this study is to compare the efficiency of smart home energy consumption to traditional home energy consumption. A machine learning model is used to predict the energy consumption used in the smart homes. It is discussed in the paper that aspect of matching the consumption of energy sources with the appropriate energy supply is regarded for being critical as the excess of energy supply can be stored until they can be converted in certain forms. There exit certain tangible benefits in monitoring closely the consumption of energy associated with buildings, they can be either office, household to commercial uses.

The aspect of developing as well as implementing energy efficient technologies can provide environmental benefits like reduced wastage, less emissions as well as enhancing economic benefits from reduced energy form as well as resource usage along with enhancing the improvement of recycling process. The machine learning algorithm for predicting energy are used for determining appropriate factors based on the global demand of future sources of global energy. In this study, an appropriate machine learning algorithm known as Light GBM is utilized for predicting the energy consumption. Other than Light GBM, some other algorithms known as ARIMA model and LSTM models are analysed and compared with one another and an efficient algorithm is determined for carrying out prediction process. The characteristic features of all these three models are analysed thoroughly and it was determined that Light GBM model is best suitable for this prediction process (Malki, Atlam and Gad, 2022). ARIMA models can be applied in the cases where the significant data representing evidence of non-stationary. On the other hand, Light GBM is considered as fast, distributed and high-performance boosting gradient framework that is associated with the algorithm of a decision tree, which is utilized for ranking, classification, prediction and other deep learning-based activities.

In the analysis section, it is seen that analysis is executed with the proper assistance of a deep learning model that provides the overall energy consumption of the smart home. The pre-processing of the selected dataset is done with the help of Keras. It is observed in the analysis section that utilities based on the pre-processing of selected dataset in keras are determined at tf.keras.preprocessing which assist for defining objects within raw data amount that are majorly utilized for training this model of deep learning. It is very necessary for the research individual to clean up the datasets. Cleaning up data is seen as one of the most important parts of machine learning. This process plays a significant part for creating model. The aspect of cleaning of data is considered as specific process which is based on removing and identifying incorrect, incomplete, inaccurate, and irrelevant data segment along with can be able to delete, modify as well as replace them depending on basic requirements (Maswadi, Ghani, and Hamid, 2020). The process of data cleaning is regarded as foundational element of data science. Data is most valuable thing for machine learning and analytics.

The main importance of deleting these unnecessary observations from the dataset is that it alters the efficiency of analysing data by greater extent. So, in this particular context of study, the selected dataset is cleaned with a parameter function called isnull(). This parameter returns object of data frame in which all segments of data are replaced with an option of true for null values as well as false option for not null values. In the data visualization part of this study, Matplotlib and Seaborn libraries are utilized. It is also mentioned in the analysis section that these libraries are considered as in-built module which assist in plotting various types of graphs. It is seen in the result section that based on analysis; model accuracy is significantly high after weather is considered. So, it can be said that weather is one of the most important things to consider when figuring out how much energy a smart home will use. Moreover, by comparing the traditional home architecture and smart home architecture, it is found that smart home consumes less energy than traditional homes, thus justifying the main purpose of research work.

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### Chapter 7: Conclusion and Recommendations

### 7.1 Conclusion

Detailed information about the energy consumption of smart homes architecture is explained through this study. The application of smart home is considered as significant as well as gas obtained fame because of increasing rate of utilization of such technologies. It is mentioned in this study that requirement of implementing the desired approach of the technology of smart home are necessary for shortage of the intelligent applications. This research study focuses primarily on delivering information regarding multiple benefits of applying the smart technology in the regular life of people. A smart home is defined in this study as specific applications as well as implementation of internet of things (IoT) playing a crucial role to enable monitoring the activities of home staying at any location. In this paper, we talk about smart home technology, which is any set of systems, appliances, and devices that are usually connected to a common network and can be controlled independently and remotely. When home technology performs together in single system, this can be discussed as a form of connected house. It is mentioned in this study that for implementing the smart home technology, there exits some requirements which are very important and must be taken into consideration like having a proper and high-speed internet connection, Wi-Fi, a smart phone, or tablet for controlling home devices, cable network etc.

The study's main goal is to evaluate the efficiency of smart home energy usage to traditional energy consumption. The research problem in this study includes the complications faced by the people living in traditional homes without any advanced technology implementation. as mentioned in the study that with traditional home technology, people were not capable of controlling all devices and appliances of their houses through a single device. The objectives are framed around the research paper's principal goal. The aim of the first objective is to find out the difference between traditional and smart home energy consumption. The second objective of this study is based on determining factors which possess potential impact on smart home energy consumption. The third objective includes designing of a model for efficient energy consumption of smart home appliances and the fourth objective is to evaluate the performance of the model as well as to predict total consumption of energy of the smart home devices. This research paper has played a major role associated with identifying and analysing the multiple reasons for utilizing different beneficial aspects of smart home technology compared to traditional homes.

Moreover, the home automation significance is also discussed in this paper. As the huge electricity demand are increasing in a rapid state now a days, so the importance of smart home implementation is in high demand. The factor IoT enabled applications provided a boon for people who are physically disabled or elderly people where those individuals can be able to monitor and control the home activities. It is also observed that the research individual has mentioned advancement of the IoT enabled applications has been the state-of art technology between many researchers because of availability of the internet servers. Moreover, detailed information is also provided while comparing the traditional homes with the smart homes. The proper tracking of energy consumed by home appliances are possible only with smart homes but not with traditional homes. The smart homes have the features of controlling the temperature and keeping it as per requirement.

In the literature section, the beneficial characteristics of IoT in smart homes are also described. Using the Internet of Things, the several objects can obtain as well as exchange data or information. IoT is regarded to connect device to sources of internet. For example, the user can determine the smart technology in the smart appliances such as wearable, automobiles as well as mobile devices. IoT emergence occurred when devices-initiated functioning in a smart way as well as are brimmed with the intelligence for enhancing the interaction with the other type of devices. It is also mentioned by research individual that smart home is considered as most searched associated features of IoT on web. In addition, detailed facts and figures associated with a machine learning model known as Light GBM is discussed in this paper. It is the framework of gradient boosting, which is based on decision trees and can improve the performance of models and reduce the amount of memory they use. Light GBM possess the potential ability of splitting tree leaf-wise as well as possess lower rate of loss when they are compared with level-wise machine learning algorithm.

Moreover, detailed information about the appropriate methodologies which are selected by the research individual to get best results are included in this paper. Philosophy, strategies, approach, method of gathering data, and method of analysing data are all explained in detail. It is mentioned in this paper that research philosophy is specific belief about the possible way where the significant data regarding a single phenomenon must be collected, analysed as well as utilized. Among the four types of philosophies, Interpretivism is selected as appropriate approach of research philosophies. On the other hand, research strategy is considered as entire plan to conduct research study. The strategy guides the research scholar in executing, planning as well as monitoring study. For this study, the research individual has selected quantitative research strategy as suitable as this study deals with numerical variables based on energy consumption. While focusing on the research approach, it is seen that deductive research approach was given more importance for this study. Appropriate techniques are also applied to carry out the analysis process efficiently so as to obtain accurate results.

### 7.2 Recommendations

In this section, some recommendations are provided to improve the overall model of smart homes. The smart homes are working environment that involves advanced technology for allowing devices as well as systems to control automatically. Some of the recommended strategies to develop and improve the operation facility of smart homes and make it more convenient to use for all aged people are discussed here. The first strategy is to test the variant options of control panel as well as manage environmental conditions of space. This is because it is known that the aspect of experiencing the home automation is considered as key to understand the significant value of smart technologies. Before installing the smart technologies, the user needs to identify what things or objects they require to control or keep track on which is the second recommended strategies for developing the experience of smart technologies in home. The main goal of a smart home is to improve the quality of life of the people who live there through automated devices and to help them live in a way that is safe, comfortable, and healthy. The third strategy is to implement advanced technologies to foster lasting binds as well as enhance social exchange among the family members. This activity of implementing advanced technologies can also emphasize the management of energy consumption as well as healthcare requirements of the aged users. The next recommended strategy is to provide convenient medical care by implementing smart health technology in homes. Moreover, pervasive computing applications can be recommended to be used in homes as they are useful to predict falls associated with changes in gait. There must be another feature in the smart home technologies which can be used to manage diet and keep track on the medicines along with remind the residents on schedules time of medicines. However, it is considered as more efficient for applying the home automation technologies for generating the integrated solutions instead of fulfilling individual operation or functions. Once the requirements of user are identified, it is recommended to the user for planning the integrated solutions which allow the controlling as well as programming of the environments. A single program must be executed by the algorithm which can justify most of the desired requirements of user. For example, while selecting predefining night environment, system must execute in single process including shutting down of lights, closing curtains as well as activating alarm. This single function of smart technology can not only prevent the hectic to manage each of actions separately but is also more convenient and effective to use by any individual.

### 7.3 Limitations

A study's limitations are usually uncontrollable and are strongly linked to the research design, statistical model constraints, financial constraints, or other reasons. To put it another way, a limitation is something that the researcher does not have control over. As a result, the study design, results, and conclusions should be clearly stated when the report is submitted (Theofanidis & Fountouki, 2019). Time is one of the important aspects of this research, this study is completely performed on the data gathered during the specific years. Also, another limitation is to give an access to the organizations who will be able to perform this methodology to analyse the energy consumption while building the smart home systems.

### 7.4 Future Scope

In this study, the importance of implementing smart technologies in home to reduce the energy consumption is described. This research study focuses primarily on delivering information regarding multiple benefits of applying the smart technology in the regular life of people. This study is performed for specific duration of the time; therefore, the future work will consider the present time as well. However, the organizations can refer these models to identify the best suitable model to analyse the energy consumption is not defined in this study. So, in future, the researchers can focus on describing the methodology for organizations or the challenges faced by people while using the smart technologies.

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| Appendix A: Research proposal plan **Enhancement of Smart Home Automation Architecture**  **INTRODUCTION AND JUSTIFICATION:**  This research report proposes the techniques related to the IOT nothing but Internet of Things and their autonomy and compatibility. Internet of Things is nothing but to enabling the modern services to physical entities based on advanced communication. These things are having ability to connect with things automatically having the set of information. What are exactly these physical entities? So, these physical entities are nothing but any day-to-day instruments. It can be absolutely any household from large things like fan, house lights, doors, window to the small things like toothbrush. Now-a-days, IOT are worldwide used technology.  Automation in home is nothing but the controlling the household things with the help of controllers and sensors. Home automation is used with the help of digital interactive interface which is connected to the household things. Automation is simply means that completing any task without any natural interference.  **RESEARCH QUESTIONS, AIMS & OBJECTIVE:**  The exact aim of this research is to automate the household things to make the house fully automated i.e. smart house systems. Our clear idea to do this research is to reduce manual interference as well as to control the power wastage. This will lead to the saving of the energy as well as the saving of the labour work. With the help of IOT we can achieve our aim by connecting the physical appliances to the sensors and make them fully automated with the integrated modern technologies.  **Research Question:**  With the help of IOT-ARM is nothing but IOT Architectural Reference Model Deliverable, derive the solution for fully automated house.  **Objective:**   * Accomplish compatibility and liberty between number of IOT things forgetting about the dominion. * Capability of devices to become abreast. * Executing similar prototype cases in the form of Developed Home Automation System Architecture extracted solutions for examinations. * The research will help us to provide the appropriate solution as well as the recommendation for the future studies related to the optimized home architecture.   **LITERATURE REVIEW:**  **Characteristics of IOT system:**  The very primary aim of this research is to provide the interconnectivity between the things. This interconnectivity can be between the number of things or users and things. We are considering the requirements completely here. The entire process is relay on the requirements.  Internet of Things is the technology which discovered for large scale. As well as it is covering the large scale area. The predictions made from the experts is over the 50 billion of things are going to be connect with the IOT. With the help of cloud IOT can scale up and the reach to the expectations. One can be easily used for their use. But the Internet of Things may require the geographical area. For implementing the IOT things, it is the main constraint minimal cost of deployment with the suitable geographical area.  The very important key aspect of the Internet of things is to monitor and to manage the entire the system and services. Basically, for the monitoring the IOT services it is mandatory to manage the application of the proven system. Management of the services is completely depends on the administration side, safety and security of the system and the control of the system.   * **Importance of Internet of Things:**   Internet-of-things are nothing but the sensing the things with the some authenticate process. Internet of things like cameras, street-lights, doors, water-taps, house alarm, public smoke alarm, bins these all leads to the smart as well as the secure environment. It may include multiple public places like big buildings, malls, public libraries, commercial apartments, houses, city campuses, university campuses and even entire cities.  Now- a-days, entire aspects are covering with the internet of things.  With the help of IOT one can easily access the automated things in the absence. There is no need to be present on the location to operate the things. Using the Internet of Things we can easily reduce the excessive use of the resources.   * **Technical side Overview:**   In the household things, one can do full automation in every aspect. With the help of monitoring and management properties of IOT household things can be regulate. It is multi- step process, but it primarily accessed for processing, sensing as well as automation. And they are interlinked with the internet and precisely accessing the MQTT, HTTP, CoAP protocols.   * **IOT referenced Model:**   In this model there are four layers: device, network, service support and application support, last one is application layer. These layers are work as stack layers. Every device is consists on its own capabilities. On the base there is Device Layer and it is consist of two capabilities. First one is the device capabilities and another one is the gateway capabilities.  Above that there is Network Layer and it is consist of again two capabilities. As name suggest it is having networking capabilities and the transport capabilities. Third one is the Service support and Application Support Layer. This layer is providing the two different capabilities generic support and specific support capabilities. Every capability is performing its own tasks according to the process.  On the top there is Application Layer and it is having only one task. And that is IOT applications. So, apart from these layers there two more part present for the IOT reference model. They are Security capabilities and Management capabilities. As name suggest security capability is providing two different types of the capabilities one is generic security and another one is specific security. Same for the management capabilities, there are generic management capabilities and specific management capabilities. So entirely combine these all aspects we can get full IOT reference model.   * **Types of sensors:**  1. **Wi-Fi**   Wi-Fi is simply means that “wireless Fidelity”. It is completely rely on the IEEE 802.11 standards. Wi-fi is most recent and it is bounded with the speed constraint. This technology is becoming the key aspect of every second technology. There are several standards comes under the IEEE 802.11. There are three different standards of this 802.11b, next one is the 802.11g and the last one is the 802.11n. Here, 802.11b is the oldest standard which was discovered earlier. And 802.11n is very recently discovered standard.   1. **ZigBee**   ZigBee is widely used technology. It is almost similar to the Bluetooth. It is considered that ZigBee is way better than the Bluetooth because of its low cost, highest security, simple to use and also it is having less power consuming capacity. But it is having few disadvantages in comparison with Bluetooth. It gives lower bandwidth as well as the lower range than Bluetooth.  ZigBee technology is having the different types of devices such as, ZED is nothing but ZigBee End Device, ZC stands for ZigBee Coordinator, ZR is nothing but Zigbee Router. Among all of them ZED is the cheaper one for manufacturing.   1. **Bluetooth:**   Bluetooth is widely using technology for lower range areas. Bluetooth is giving the lower range area access. It is applicable only for the small distance i.e. 100m only. The use of the Bluetooth is very limited; it is used for devices like mobile phones, mouse, keyboards, and remote control.  **RESEARCH DESIGN:**  Research design is associated with the terms, procedure and the technologies used for the developing and deploying the project from the understanding the project to delivery of the project.   * **Methodology:**   The very first and key methodology is nothing but the managing the project. For the accurate procedure here I have selected the Waterfall model. With the help of Royce’s Waterfall Model one can easily go step by step. From accessing the requirements to the planning and to the delivering the project.    **Implementation**  **System Requirements**  **Planning**  **Analysis**  **Deploy**  **Testing**    *Fig.: Methodology cycle*  There is six steps procedure for the project methodology. For the first step we need to understand the system requirements and the according to that we can analyse the software requirements. After gathering of all the requirements we need to focus on the planning. It is said that successful planning leads to the successful delivery of the project.  After completing the planning for the project implementation is the next step to achieve. For implementation of the project we need to focus on the software that we are going to use. Eclipse based Code Composer Studio will be our priority to access the coding part. It will be the most suitable Integrated Development Environment (IDE). For implementation of the process we are considering the C and C++ concepts. As well as some microprocessors and some sensors will be the part of the implementation.  Testing and Analysis will be the important and next steps for completing the project. After completion of all the aspects deployment is last step. Which is most highlighted part of the procedure.   * **Home Automation Controlled Unit (HACU):**   HACU and the UCU is nothing but User Control Units are two unites which are used by ZigBee. Basically they are attached with each other wirelessly. With the help of the star topology one can easily connect the that units with each other.   * **Wi-Fi automated smart homes:**   This is one of the way to make house fully automated and smart. In practise this technique needs the Tag4m devices to make home wi-fi based smart homes. With the help of Tga4m we can control lights, household machines, home temperature, alarm system. In the temperature section, we can control the temperature, we can display and we can do programming related to temperature.  Same for the alarm system as well, we can activate the alarms and then we can monitor the alarm. Tag4m is very useful for that. In the part of lights, we can easily program the function for accessing the lights control. One can easily on/off the lights. In case of machines, we can check the power consumptions well as we can regulate the machine automatically.  There are two different cases two implements the technologies for the smart houses. We ca say that subsystems for automation of home. The very first one is manually implemented technologies, but it should require the modifications. As it is manually fitted after certain duration, there is always need to modify the system. In this four common thing are presented. First one is the System interface gateway, it gives the interface for the system to access the system. Another one is master control and managing system, in this we need to focus on the entire control of the system as well as we need to have proper management for the accessing this.  Third aspect of this is Multi Layered Network Gateway. In this , we are focusing on the multi layered networks for the system. With the help of it we can easily have the home control. But again, it is one of the way of manually fitted technology. And the last one is the automated sub system network. Here we are focusing the sub system networks for the smart home.  Another way of doing all this is We can do all this with the help of software services. As we know that we can access the software services with the help of the cloud or internet. In this, we concentrating on the solution provided by the software. Here System interface is created over the cloud/ internet. As it is not manually implemented, there is no need to do physical interference in this. Only need to update the commands according to the requirements.   * **Hardware Requirements:**   For installing all these system, there I need of hardware assets. As we are focusing on home automation, we can consider the four things’ lights, control switches, temperature, fan. For accessing these things, we need four type of controllers or the sensors. They are as follow:   1. Light controller IOT things 2. Temperature controller IOT Things 3. Control switches IOT Things 4. Fan controller IOT Things   After implementing all these sensors, they should irk automatically as per the requirements. There for there is need to do some software programming for them. With the help of some libraries related to the ARM as well as the C programming language, we can easily control the sensors. And also we can set the as per our demands. There are some constraints to thing about all this, they are time constraint, sensing constraints, speed constraint, etc. For each and every device there are different set of the instructions. And each sensor is programmed differently for the use as per their specification of the task.   * **Non-functional Aspects:**   Easy handling: Any sensor and its related any programming or the software instruction set should be user friendly. So that user will easily understand the functioning of the devices.  Safety: There should be proper safety while developing all these controllers. It should not harm the natural or any manmade entities. It should be naturally accessible and should be less harmful.  **ETHICS, RISK AND ISSUES:**  While implanting the project there is no any ethical issues from the software development end. It is considered previously that this task will not harmful for the data privacy. There is no violation related to the data privacy as well as no violation related to the authentication. Whatever the dataset requires for the project is completely depends on the real-time case scenario. There is no other purpose to have historical data other than for analysis. The real-time data we can use for processing and research related to the work.  It is always a mandatory task to check the existing dataset as well as previous datasets for authentication and validation.   * **Risk:**   There are several risks we need to keep in mind for developing this project. Planning and executing risk, requirement risk and technical risk. There can be executing risk if we don’t have proper planning. If we have not received the accurate requirements on time then it can be huge risk related to the requirements. To avoid the technical risk, we should consider the proper execution of the services as well the accurate terms and technologies related to technical aspects.  **TIME PALN:**  This project will take the 16 weeks of time. Frome June 1st, 2021, to September 29th 2021. Time plan has helped us for managing the task during this defined time. Below given the time gantt chart for the project analysis and the execution. With the help of this plan, we easily achieve the target result in the given duration.      *Fig.: Gantt Chart*  **References:**  Papers:   1. Jayavardhana Gubbi, Rajkumar Buyya, Slaven Marusic, Marimuthu alaniswami, Nicole, “Internet of Things (IoT): A Vision, Architectural Elements, and Future Directions”, ELSEVER, Future Generation Computer Systems Volume 29, Issue 7, September 2013, Pages 1645–1660 2. Yashiro, Kobayashi, Koshizuka, Sakamura, “An Internet of Things (IoT) architecture for embedded appliances”, 26-29 Aug. 2013, IEEE, Humanitarian Technology Conference. 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International Telecommunication Union ITU, “Overview of the Internet of   things”, Next Generation Networks – Frameworks and functional architecture models, Recommendation ITU-T Y.2060, June 2012.   1. Gil Reiter, “Wireless connectivity for the Internet of Things”, Texas Instruments, June 2014, Available at [http://www.ti.com](http://www.ti.com/) 2. “Introduction to the Architectural Reference Model for the Internet of Things”, IoT-A, available at [http://www.iot-a.eu/arm.](http://www.iot-a.eu/arm) |
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### Appendix B: UREC1 Form

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# **UREC 1 RESEARCH ETHICS REVIEW FOR STUDENT RESEARCH WITH NO HUMAN PARTICIPANTS OR DIRECT COLLECTION OF HUMAN TISSUES, OR BODILY FLUIDS.**

All University research is required to undergoethicalscrutiny to comply with UK law.TheUniversityResearchEthicsPolicy (<https://www.shu.ac.uk/research/excellence/ethics-and-integrity/policies>) shouldbeconsultedbeforecompletingtheform. The initial questions are there to check that completion of the UREC1 is appropriate for this study. The supervisor will approve the study, but it may also be reviewedbythe College Teaching ProgramResearch EthicsCommittee (CTPREC) as part of the quality assurance process(additional guidance can be obtained fromyour College Research Ethics Chair[[1]](#footnote-1))

The finalresponsibility forensuringthatethicalresearchpracticesare followedrestswiththe supervisor forstudent research.

Notethatstudentsandstaffareresponsibleformakingsuitablearrangements to ensure compliance with the General Data Protection Regulations (GDPR),forkeepingdata secure andifrelevant, forkeepingtheidentity of participants anonymous. Theyare also responsiblefor followingSHU guidelinesabout dataencryption and research data management.Guidance can be found on the SHU Ethics Website <https://www.shu.ac.uk/research/excellence/ethics-and-integrity>

Please note that it is mandatory for all students to only store data on their allotted networked drive space and not on individual hard drives or memory sticks etc.

The present formalsoenablestheUniversityandCollege to keepa recordconfirmingthatresearch conductedhasbeensubjectedtoethical scrutiny.Studentsshouldretainacopy forinclusionintheirresearchprojects,anda copyshould be uploaded to the relevant module Blackboard site.

Theformmustbecompletedbythestudentandapproved bysupervisorand/or moduleleader(asapplicable).Inallcases,itshouldbecounter-signedbythesupervisor and/or moduleleaderandkeptas arecord showing thatethicalscrutinyhas occurred. Studentsshouldretainacopy forinclusioninthe appendices of theirresearchprojects,anda copy should be uploaded to the module Blackboard site for checking.

Pleasenote that itmaybenecessarytoconduct ahealthandsafetyriskassessmentforthe proposedresearch. Furtherinformationcanbeobtainedfrom the[University’s Health and Safety Website](https://sheffieldhallam.sharepoint.com/sites/3005/healthandsafety/HRRRC/SitePages/Risk-Assessment-Toolkit---Teaching-and-Research.aspx)

| **Details** |  |
| --- | --- |
| Nameofstudent | Komal Pandharinath Dhondkar |
| SHU email address | c0028753@my.shu.ac.uk |
| Department/College | Computing/ Sheffield Hallam University |
| Nameofsupervisor | Dr. Hemlata Sharma |
| Supervisor’s email address | [hs9000@exchange.shu.ac.uk](mailto:hs9000@exchange.shu.ac.uk) |
| Titleofproposedresearch | Enhancement of smart home automation architecture |
| Proposedstartdate | 23rd January 2022 |
| Proposedenddate | 9th May 2022 |
| Brief outline of research to include, rationale (reasons) for undertaking the research & aims, and methods (250-500 words). | The smart home is one of the most emerging technologies in the recent time because of implementation of IoT devices. The smart home helps to provide the better security as well as the energy saving technologies. The primary aim of this study is to analyze the effectiveness of the smart home energy consumption in contrast to the traditional home. For the high energy consumptions of the household, the effective as well as intelligent system needs to implement in the homes that can reduce the energy usage as well as increases the security of the home. All the IoT devices of the smart home are connect to the single network that helps to provide the effective operations of the devices. Apart from this, these devices keep the appropriate track of the energy consumptions that helps to reduce the energy consumption of the smart home. The primary problem of this study is to reduce the energy consumption of household. The traditional home consumes a lot of energy that can increase the expenses of the household. In this study, the data is collected from the secondary sources and the quantitative research method is utilized. For this paper, machine learning model is used that helps to predict the energy consumption of the smart home based on several factors such as weather, temperature, and time. For the machine learning model, the LSTM, ARIMA and LGB algorithms are used. After predicting the value of the energy consumption, it is compared to the value with the traditional house energy consumption data that helps to provide the accurate result for answering the research questions. |

I confirm that this study does not involve collecting/using data or samples from human participants

Please tick□ ✓

## **2.Research in external organizations**

| **Question** | **Yes/No** |
| --- | --- |
| 1. Will theresearchinvolveworkingwith/withinanorganization(e.g., school, business,charity, museum,governmentdepartment, international agency, etc.)? | No |
| 1. IfyouansweredYES toquestion1, do youhavegrantedaccesstoconduct theresearch?   *If YES,studentspleaseshow evidencetoyour supervisor. PI shouldretain safely.* |  |
| 1. IfyouansweredNO toquestion2, isit because:    1. youhavenotyet asked    2. youhaveaskedandnotyet receivedananswer    3. youhaveaskedandbeen refusedaccess.   *Note: You will onlybeable to start theresearchwhen youhavebeengranted access.* |  |

## **Research with Products and Artefacts**

| **Question** | **Yes/No** |
| --- | --- |
| 1.Will theresearchinvolveworkingwithcopyrighteddocuments, films, broadcasts, photographs,artworks, designs, products, programs, databases, networks,processes, existing datasets,orsecuredata? | No |
| 2.IfyouansweredYES toquestion1, arethematerialsyouintend touseinthe publicdomain?  *Notes: ‘In thepublicdomain’doesnot meanthesamethingas‘publiclyaccessible’.*   * *Informationwhichis'inthepublicdomain' isnolongerprotectedby copyright (i.e.,copyrighthaseither expiredor been waived)andcanbe usedwithout permission.* * *Informationwhichis'publiclyaccessible'(e.g., TVbroadcasts, websites, artworks, newspapers)isavailable for anyoneto consult/view. Itisstill protectedbycopyright evenif thereisnocopyrightnotice. InUK law, copyright protectionisautomaticanddoesnot requireacopyright statement, althoughit isalwaysgoodpracticetoprovideone. It is necessarytocheckthetermsandconditionsofuse tofindout exactly how thematerialmaybereusedetc.*   *If youansweredYEStoquestion1, beawarethatyoumayneedtoconsider other ethicscodes.Forexample, whenconducting Internet research, consult thecodeof theAssociationof InternetResearchers; foreducational research, consult theCodeof Ethicsof theBritishEducational Research Association.* |  |
| 3.IfyouansweredNO toquestion2, do youhaveexplicitpermissiontouse thesematerialsasdata?  *If YES,pleaseshowevidence toyour supervisor.* |  |
| 4.IfyouansweredNO toquestion3, isit because:  A.youhavenotyet askedpermission  B.youhaveaskedandnotyet receivedandanswer  C.youhaveaskedandbeen refusedaccess.  *Note You will onlybeable to start theresearchwhen youhavebeengranted permissiontousethespecified material.* |  |

1. **Does this research project require a health and safety risk assessment for the procedures to be used?** Discuss this with your supervisor and consult the [Risk Assessment Toolkit](https://sheffieldhallam.sharepoint.com/sites/3005/healthandsafety/HRRRC/SitePages/Risk-Assessment-Toolkit---Teaching-and-Research.aspx) for teaching research.

Yes

No ✓

(If **YES** the completed Health and Safety Risk Assessment form should be attached). You can find a Blank/Sample Risk Assessment Form at the Checklist, Generic and TORS Risk Assessments on the [Risk Assessment Toolkit](https://sheffieldhallam.sharepoint.com/sites/3005/healthandsafety/HRRRC/SitePages/Risk-Assessment-Toolkit---Teaching-and-Research.aspx)

## **Adherence to SHU policy and procedures**

| **Ethics sign-off** | |
| --- | --- |
| **Personalstatement** | |
| Icanconfirm that:   * Ihave readtheSheffieldHallamUniversity ResearchEthicsPolicyandProcedures * Iagreetoabideby itsprinciples. | |
| **Student** | |
| Name:Komal Pandharinath Dhondkar | Date: 25th January 2022 |
| Signature: Text, letter  Description automatically generated | |
| **Supervisororanotherpersongivingethicalsign-off** | |
| Icanconfirm that completionofthisform has confirmed that this research does not involve human participants. Theresearchwill notcommence until anyapprovals requiredunderSections2&3havebeen received and any health and safety measures are in place. | |
| Name: Dr. Hemlata Sharma | Date: 03/05/2022 |
| A picture containing text, whiteboard  Description automatically generatedSignature: | |
| Additional Signature if required: | |
| Name: | Date: |
| Signature: | |

**Please ensure that you have attached all relevant documents. Your supervisor must approve them before you start data collection:**

| **Relevant Documents** | **Yes** | **No** | **N/A** |
| --- | --- | --- | --- |
| Research proposal if prepared previously | ✓ |  |  |
| Any associated materials (e.g., posters, letters, etc.) |  |  | ✓ |
| Health and Safety Risk Assessment Form |  |  | ✓ |

### Appendix C: Code

import numpy as np

import pandas as pd

import holoviews as hv

from holoviews import opts

hv.extension('bokeh')

from matplotlib import pyplot as plt

import seaborn as sns

import os

import changefinder

from scipy import stats

from statsmodels.tsa.api import VAR

from statsmodels.tsa.stattools import grangercausalitytests

from statsmodels.tsa.stattools import adfomeuller

from fbprophet import Prophet

from sklearn.metrics import mean\_absolute\_error

import lightgbm as lgb

from sklearn.preprocessing import LabelEncoder

from tabulate import tabulate

from IPython.display import HTML, display

for dirname, \_, filenames in os.walk('/kaggle/input'):

    for filename in filenames:

        print(os.path.join(dirname, filename))

shome = pd.read\_csv("/content/HomeC (1).csv",low\_memory=False)

print(f'HomeC.csv : {shome.shape}')

shome.head(3)

shome.columns

shome.columns = [i.replace(' [kW]', '') for i in shome.columns]

shome['Furnace'] = shome[['Furnace 1','Furnace 2']].sum(axis=1)

shome['Kitchen'] = shome[['Kitchen 12','Kitchen 14','Kitchen 38']].sum(axis=1)

shome.drop(['Furnace 1','Furnace 2','Kitchen 12','Kitchen 14','Kitchen 38','icon','summary'], axis=1, inplace=True)

shome = shome[0:-1]

shome.info()

fig,ax = plt.subplots(figsize=(10, 8))

corr = shome[['Dishwasher','Home office','Fridge','Wine cellar','Garage door','Barn','Well','Microwave','Living room','Furnace','Kitchen']].corr()

sns.heatmap(corr, annot=True, vmin=-1.0, vmax=1.0, center=0)

ax.set\_title('Correlation of Appliances',size=20)

plt.show()

fig,ax = plt.subplots(figsize=(10, 8))

corr = shome[['temperature','apparentTemperature','humidity','visibility','pressure','windSpeed','cloudCover','precipIntensity','dewPoint']].corr()

sns.heatmap(corr, annot=True, vmin=-1.0, vmax=1.0, center=0)

ax.set\_title('Correlation of Weather Information',size=20)

plt.show()

import numpy as np

import pandas as pd

import matplotlib

import matplotlib.pyplot as plt

import seaborn as sns

%matplotlib inline

smart = pd.read\_csv("/content/HomeC (1).csv",low\_memory=False)

print(f'HomeC.csv : {shome.shape}')

smart.head(3)

tmp\_str = "Feature(attribute)     DataType"; print(tmp\_str+"\n"+"-"\*len(tmp\_str))

print(smart.dtypes)

print("Shape of the data: {} --> n\_rows = {}, n\_cols = {}".format(smart.shape, smart.shape[0],smart.shape[1]))

smart.head(10)

smart.tail(10)

smart = smart[0:-1]

smart.tail()

np.r\_[0:5, -5:0]

smart.iloc[np.r\_[0:5, -5:0]]

smart.columns

smart.columns = [col.replace(' [kW]', '') for col in smart.columns]

smart.columns

smart['sum\_Furnace'] = smart[['Furnace 1','Furnace 2']].sum(axis=1)

smart['avg\_Kitchen'] = smart[['Kitchen 12','Kitchen 14','Kitchen 38']].mean(axis=1)

smart = smart.drop(['Kitchen 12','Kitchen 14','Kitchen 38'], axis=1)

smart = smart.drop(['Furnace 1','Furnace 2'], axis=1)

smart.columns

smart['time'].head()

import time

print(' start ' , time.strftime('%Y-%m-%d %H:%M:%S', time.localtime(int(smart['time'].iloc[0]))))

time\_index = pd.date\_range('2016-01-01 05:00', periods=len(smart),  freq='min')

time\_index = pd.DatetimeIndex(time\_index)

smart = smart.set\_index(time\_index)

smart = smart.drop(['time'], axis=1)

smart.iloc[np.r\_[0:5,-5:0]].iloc[:,0]

smart.shape

smart['temperature'].plot(figsize=(25,5))

smart['temperature'].resample(rule='D').mean().plot(figsize=(25,5))

import matplotlib.pyplot as plt

plt.rcParams["figure.figsize"] = (25,5)

smart.columns

fig, axes = plt.subplots(nrows=2, ncols=1)

smart['use'].resample('D').mean().plot(ax=axes[0])

smart['House overall'].resample('D').mean().plot(ax=axes[1])

smart = smart.drop(columns=['House overall'])

smart.shape

smart['icon'].value\_counts()

smart = smart.drop(columns=['summary', 'icon'])

smart.shape

smart['cloudCover'].unique()

smart[smart['cloudCover']=='cloudCover'].shape

smart['cloudCover'][56:60]

smart['cloudCover'].replace(['cloudCover'], method='bfill', inplace=True)

smart['cloudCover'] = smart['cloudCover'].astype('float')

smart['cloudCover'].unique()

smart['cloudCover'][56:60]

smart.info()

smart = smart.resample('H').mean()

print("Shape of hourly smart: {} --> n\_rows = {}, n\_cols = {}".format(smart.shape, smart.shape[0],smart.shape[1]))

smart['Microwave'].resample("h").mean().iloc[:24].plot()

smart.groupby(smart.index.hour).mean()['Microwave'].plot(xticks=np.arange(24)).set(xlabel='Daily Hours', ylabel='Microwave Usage (kW)')

from sklearn.metrics import r2\_score, median\_absolute\_error, mean\_absolute\_error

from sklearn.metrics import median\_absolute\_error, mean\_squared\_error, mean\_squared\_log\_error

def mean\_absolute\_percentage\_error(y\_true, y\_pred):

    return np.mean(np.abs((y\_true - y\_pred) / y\_true)) \* 100

def plotMovingAverage(series, window, plot\_intervals=False, scale=1.96, plot\_anomalies=False):

    rolling\_mean = series.rolling(window=window).mean()

    plt.figure(figsize=(25,5))

    plt.title("Moving average with window size = {}".format(window))

    plt.plot(rolling\_mean, "g", label="Rolling mean trend")

    if plot\_intervals:

        mae = mean\_absolute\_error(series[window:], rolling\_mean[window:])

        deviation = np.std(series[window:] - rolling\_mean[window:])

        lower\_bond = rolling\_mean - (mae + scale \* deviation)

        upper\_bond = rolling\_mean + (mae + scale \* deviation)

        plt.plot(upper\_bond, "r--", label="Upper Bond / Lower Bond")

        plt.plot(lower\_bond, "r--")

        if plot\_anomalies:

            anomalies = pd.DataFrame(index=series.index, columns=series.columns)

            anomalies[series<lower\_bond] = series[series<lower\_bond]

            anomalies[series>upper\_bond] = series[series>upper\_bond]

            plt.plot(anomalies, "ro", markersize=10)

    plt.plot(series[window:], label="Actual values")

    plt.legend(loc="upper left")

    plt.grid(True)

n\_samples = 24\*30

cols = ['use']

plotMovingAverage(smart[cols][:n\_samples], window=6)

def exponential\_smoothing(series, alpha):

    result = [series[0]]

    for n in range(1, len(series)):

        result.append(alpha \* series[n] + (1 - alpha) \* result[n-1])

    return result

def plotExponentialSmoothing(series, alphas):

    with plt.style.context('seaborn-white'):

        plt.figure(figsize=(25, 5))

        for alpha in alphas:

            plt.plot(exponential\_smoothing(series, alpha), label="Alpha {}".format(alpha))

        plt.plot(series.values, "c", label = "Actual")

        plt.legend(loc="best")

        plt.axis('tight')

        plt.title("Exponential Smoothing")

        plt.grid(True);

n\_samples = 24\*30

col = 'use'

plotExponentialSmoothing(smart[col][:n\_samples], [0.3, 0.05])

from statsmodels.tsa.arima\_model import ARIMA

def forcast\_ts(data, tt\_ratio):

    X = data.values

    size = int(len(X) \* tt\_ratio)

    train, test = X[0:size], X[size:len(X)]

    history = [x for x in train]

    predictions = list()

    for t in range(len(test)):

        model = ARIMA(history, order=(5,1,0))

        model\_fit = model.fit(disp=0)

        output = model\_fit.forecast()

        yhat = output[0]

        predictions.append(yhat)

        obs = test[t]

        history.append(obs)

        print('progress:%',round(100\*(t/len(test))),'\t predicted=%f, expected=%f' % (yhat, obs), end="\r")

    error = mean\_squared\_error(test, predictions)

    print('\n Test MSE: %.3f' % error)

    plt.rcParams["figure.figsize"] = (25,10)

    preds = np.append(train, predictions)

    plt.plot(list(preds), color='green', linewidth=3, label="Predicted Data")

    plt.plot(list(data), color='blue', linewidth=2, label="Original Data")

    plt.axvline(x=int(len(data)\*tt\_ratio)-1, linewidth=5, color='red')

    plt.legend()

    plt.show()

col = 'use'

data = smart[col].resample('w').mean()

data.shape

tt\_ratio = 0.70

forcast\_ts(data, tt\_ratio)

col = 'use'

data = smart[col].resample('d').mean()

data.shape

tt\_ratio = 0.70

forcast\_ts(data, tt\_ratio)

from sklearn.model\_selection import TimeSeriesSplit

X = np.array([[1, 2], [3, 4], [1, 2], [3, 4], [1, 2], [3, 4]])

y = np.array([1, 2, 3, 4, 5, 6])

tscv = TimeSeriesSplit(n\_splits=5)

print(tscv)

for train\_index, test\_index in tscv.split(X):

    print("TRAIN:", train\_index, "TEST:", test\_index)

    X\_train, X\_test = X[train\_index], X[test\_index]

    y\_train, y\_test = y[train\_index], y[test\_index]

import keras

from keras.models import Sequential

from keras.layers import Dense, Dropout

from keras.layers import LSTM

keras.\_\_version\_\_

weather\_features = smart[['temperature','humidity', 'visibility','windSpeed', 'pressure', 'cloudCover', 'windBearing', 'precipIntensity','precipProbability']]

energy\_use = smart['use']

x\_train = weather\_features[:7000]

y\_train = energy\_use[:7000]

x\_test = weather\_features[7000:]

y\_test = energy\_use[7000:]

x\_train = np.reshape(x\_train.values, (x\_train.shape[0], x\_train.shape[1], 1))

x\_test = np.reshape(x\_test.values, (x\_test.shape[0], x\_test.shape[1], 1))

x\_train.shape, y\_train.shape, x\_test.shape, y\_test.shape

model = Sequential()

model.add(LSTM(units=32, return\_sequences=True, input\_shape=(x\_train.shape[1], 1)))

model.add(LSTM(units=32))

model.add(Dense(units = 1))

model.compile(optimizer = 'adam', loss = 'mean\_squared\_error')

model.summary()

model.fit(x\_train, y\_train, epochs = 5, batch\_size = 32)

predictions = model.predict(x\_test)

plt.figure(figsize=(25,10))

plt.plot(y\_test.values[::24], color='blue', label='Original Usage')

plt.plot(predictions[:,0][::24] , color='red', label='Predicted Usage')

plt.title('Energy Usage Prediction')

plt.xlabel('Date')

plt.ylabel('kW')

plt.legend()

plt.show()

weather\_features = smart[['temperature','humidity', 'visibility','windSpeed', 'pressure', 'cloudCover', 'windBearing', 'precipIntensity','precipProbability']]

energy\_use = smart['use']

weather\_features = weather\_features['2016-01-02 05:00:00':'2016-12-02 05:00:00']

weather\_features['yesterday\_use'] = energy\_use['2016-01-01 05:00:00':'2016-12-01 05:00:00'].values

energy\_use = smart['use']['2016-01-02 05:00:00':'2016-12-02 05:00:00']

weather\_features.shape, energy\_use.shape

x\_train = weather\_features[:5000]

y\_train = energy\_use[:5000]

x\_test = weather\_features[5000:]

y\_test = energy\_use[5000:]

x\_train = np.reshape(x\_train.values, (x\_train.shape[0], x\_train.shape[1], 1))

x\_test = np.reshape(x\_test.values, (x\_test.shape[0], x\_test.shape[1], 1))

x\_train.shape, y\_train.shape, x\_test.shape, y\_test.shape

model = Sequential()

model.add(LSTM(units=32, return\_sequences=True, input\_shape=(x\_train.shape[1], 1)))

model.add(LSTM(units=32))

model.add(Dense(units = 1))

model.compile(optimizer = 'adam', loss = 'mean\_squared\_error')

model.summary()

model.fit(x\_train, y\_train, epochs = 5, batch\_size = 32)

predictions = model.predict(x\_test)

plt.figure(figsize=(25,10))

plt.plot(y\_test.values[::24], color='blue', label='Original Usage')

plt.plot(predictions[:,0][::24] , color='red', label='Predicted Usage')

plt.title('Energy Usage Prediction')

plt.xlabel('Date')

plt.ylabel('kW')

plt.legend()

plt.show()

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*Taranveer S. Anttal(2016)Smart home dataset with weather Information (Version 1.0) [source code] https://www.kaggle.com/*

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### APPENDIX D: DATASET DISCRIPTION

|  |  |  |
| --- | --- | --- |
| **Column name** | **Datatype** | **Column Description** |
| Time | Object | It is a time span of 1 minute of 350 days. |
| Use | Float64 | It is total energy consumption of the house in kilowatt |
| Gen | Float64 | Generation of total energy of solar or any other resources |
| House overall | Float64 | Overall energy consumption of the house in kilowatt |
| Dishwasher | Float64 | Energy consumed by the dishwasher in kilowatt |
| Furnace 1 | Float64 | Energy consumed by furnace 1 |
| Furnace 2 | Float64 | Energy consumed by furnace 2 |
| Home Office | Float64 | Energy consumed by home office |
| Fridge | Float64 | Energy consumed by fridge |
| Wine cell | Float64 | Energy consumed by wine cell |
| Garage door | Float64 | Energy consumed by garage door |
| Kitchen 12 | Float64 | Energy consumed by kitchen 1 |
| Kitchen 14 | Float64 | Energy consumed by kitchen 2 |
| Kitchen 38 | Float64 | Energy consumed by kitchen 3 |
| Barn | Float64 | Energy consumed by barn |
| Well | Float64 | Energy consumed by well |
| Microware | Float64 | Energy consumed by microwave |
| Living room | Float64 | Energy consumed by living room |
| Solar | Float64 | Energy consumed by solar |
| Temperature | Float64 | Overall temperature |
| Icon | Object | Showing total weather scenario |
| Humidity | Float64 | Overall humidity |
| Visibility | Float64 | Overall visibility |
| Summary | Object | Shows overall summary of the weather |
| Apparent temperature | Float64 | Shows apparent temperature |
| Pressure | Float64 | Shows total pressure |
| Cloud cover | object | shows cloud cover condition |
| Windbearing | Float64 | Shows wind bearing |
| Windspeed | Float64 | Shows total windspeed |
| Precipitation intensity | Float64 | Shows total precipitation intensity |
| Dewpoint | Float64 | Shows dewpoint |
| Precipprobability | Float64 | Shows precipitation probability |

Figure: Dataset information

(Source: (Anttal, 2016)- https://www.kaggle.com/datasets/taranvee/smart-home-dataset-with-weather-information?select=HomeC.csv)

### Appendix E: Discussion and Conclusion

It is explained in this paper that with the rising occurrence of the personal threats as well as burglary and property damage, it has become very significant to implement effective system of smart technologies in home so that security is maintained. In these modern times, security and safety over lives and properties can typically be considered the major concerns that need to be prioritized. To achieve safety, convenience, and security and manage a home, the requirement specifically rises for a system of intelligent homes which is the smart homes. It is described in this study that with the guidance of smart home technologies, people can be able to connect all their devices of home through smart phones that are effective to gain more specified control over their surroundings and homes. On the other hand, smart home technology can also be a very good way to make new appliances and devices more flexible.

In the literature review section, the various view points and opinions of different authors who had carried out their research on similar topic are analysed and evaluated to obtain better understanding of the research work. It is mentioned in this section that energy consumption of smart home is capable specifically to reduce costs as well as generate certain instant changes in people’s homes. The research individual has described in the literature section about the background of smart home systems so that the audience can get a clear idea regarding the technologies and architecture in smart homes. It is referred to the prior utilization of information technology and computer systems to control the features of home appliances like lighting and windows. From what different authors have said, it's clear that certain systems can be as simple as a remote-controlled light switch or as complicated as a microcontroller based on a network, with different levels of automation and intelligence. It is described in this study that in architectures of smart homes, it is very common that all types of components in networks of home can be controlled by home gateway which acts as a form of service provider for the users. Smart home gives a lot of beneficial aspects to the people. It saves huge amount of energy as well as heat as compared to the traditional homes. The technology of smart homes holds the potential ability for making life convenient and easier. It provides the tremendous benefits for the elderly people and people with disabilities to live alone without any worries.

In this study, machine learning algorithm generate probable values depending on unknown variable for every definite type of records in a desired form of information or data that can allow the user in building machine learning model to identify that desired amount of value that is accurate for carrying out the prediction process (Aïvodji, Gambs and Martin, 2019). The model predictions of machine learning allow the user for making high accurate and desirable guess as based on the likely outcomes. This may also provide the user with the definite insights that may result in tangible value based on business activities.

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