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Analytics for IoT Prototyping

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Abstract- *Information technology is creating a revolution among the products. The products which were once only made up of mechanical and electrical parts are now a combination of hardware, sensors, cloud, controllers, software and internet connectivity. These products have unleashed an era of smartness. They have the capability to connect everything, everyone and everywhere. IoT is the everlasting concept of connecting things through internet connectivity. IoT provides connectivity beyond the traditional devices like desktop, laptops, smartphones and tablets to a wide variety of things used every day and uses embedded technology to connect with external surroundings.*

This technology allows devices to create exchange and use data automatically without human interruptions. The Smart products have three essential components: physical components such as physical products, and smart component such as sensors, microprocessors etc., and connectivity component such as ports, Antennae etc. These components are interdependent and strengthen each other's capabilities. The smart products excel in four areas: monitoring, controlling, optimization and autonomy. These products can self-coordinate and function with complete autonomy. Human managers can focus on system's performance rather than single units, hence increasing experience and effectiveness. IoT based solutions when introduced in business, result in higher quality products, which are according to the conformance of standards.

In this study, by understanding the process of IoT solutions by building prototypes of IoT using the hardware components required, in the areas of Automated Street light system (ASLS) which uses sensors and gets switched ON and switched OFF when it senses movement, Smart irrigation system (SIS) is a sensor based irrigation system which irrigates the land whenever the moisture content falls below the required threshold value and Voice controlled home automation system (VCHAS) which uses speech to text in order to convert speech information into text. This system can switch ON or OFF the bulb, fans, AC, Fridges and other electronic appliances through voice instructions and testing them. The data returned by the system through smart devices gives managers visibility to analyze the results which leads them to quick decision making and forecasting the future necessity. The smart products raise the value for the consumers by decreasing operating costs, increasing efficiency and improving output. The potential benefits of data generated by the IoT sensors has been unfolded using machine learning techniques

.These techniques have been used on moisture content data of 15 villages generated by the sensors,in order to identify drought in early stages. This study focuses on implementation of IoT prototypes only on the chosen areas, which are smart irrigation system, automated street light system and voice controlled home automation system. The machine learning techniques such as Auto regressive models (AR), Artificial Neural Networks (ANN), and Support Vector Machines (SVM) on these applications. The study is restricted to the only selected solutions of IoT in few operation

Keywords: *IoT, Machine Learning, IoT solutions*

1. Introduction

IoT has ability to disrupt businessess by increasing their efficiency and their business models have to be transformed accordingly. This creates a need for a proper framework for businesses to create value. IoT is a significant tool useful in efficient management of resources such as human, financial assets, products and information. Hence, improving the management of the company and business. This technology is at the core of business existence today. With billions of connection of devices in the world, the IoT is not a Sci-Fi concept it is the realism we live in. India, with the support of government is also becoming an IoT hub with its rapid progress in IoT. Global trends in lighting of street lights prove that 18-38% of the total energy bill goes towards street lighting and this is why, this is one of the areas that need more attention if we look at reducing power consumption **(MyIndia, 2015).** In India Agriculture is the major source of revenue in India. 70 percent of its rural households still depend primarily on agriculture for their livelihood. As majority of rural families depend on agriculture for living, these causes a necessity for smart irrigation to save water resources. Home automation has capacity to save energy, hence reducing the power consumption. And unleashing the potential of data generated by the IoT devices and their analysis using machine learning techniques is useful in predicting the future.

This is an applied research which focuses on solving the problems in the field of irrigation, street lighting system and home automation with the help of IoT solutions. The project aims at unleashing the potential of the IoT and the data generated by it. Three IoT prototypes have been built using the hardware components required. The data generated by the sensors of the IoT prototypes are analyzed to gain insights. The moisture content data used in objective 2 has been obtained from the 15 villages using moisture content sensor. The moisture content has been analyzed and forecasted using, MST, ANN, AR models and SVM. These techniques are useful to make predictions in time series data. As the data generated by IoT sensors are time series data, these tools are very efficient in the analysis. The cost-effectiveness of IoT has been depicted by comparing the benefits before and after using the IoT solutions. A descriptive study on IoT business model framework has been made, so that a business model framework can be suggested for the prototypes built.

The data is generated after implementing and testing the prototypes built in objective 1 and data is primary. This data is generated by the sensors embedded in irrigation system and Automatic street light system. The data of voice samples is collected through the mic provided in the Voice controlled home automation system[1]. The data used in the second objective for analysis and forecasting purposes has been obtained from moisture sensors from 15 villages and is a primary data source shown in **Annexure 2(**15 days sample out of 120 days sample has been enclosed as it is difficult to enclose 2880 observations of 15 villages**).**

In objective 1 the IoT prototypes have been built using hardware components like sensors, Arduino, etc. and by programming the microcontrollers. Some of the implementations of the IoT prototypes have been done in a simulated and some in a real-time environment. The smart irrigation system has been implemented on 2 pots, one is pot 0 and another is pot 1 which has soils of drought and cultivatable respectively. The prototype of automated street lighting system has been implemented on streets in real time. The light present in the prototype switches ON whenever a movement is detected on the street. The voice controlled home automation has been implemented real time. About 100 samples of voices have been taken through the mic present in the system. In objective two the primary data of moisture content of the soils from 15 villages has been used for analyzing and forecasting purposes in order to identify drought prior to its occurrence. The minimum spanning tree algorithm has been used on the moisture content data of the soil. The data has been generated from real-time environment i.e. agricultural fields to understand the network topology of the agricultural lands w.r.t moisture in soil at various plant stages. The model with minimum error in prediction of moisture content among ANN, AR models and SVM has been

[1] Voice controlled home automation system(VCHAS)

identified. Among these models, the model which gives the most accurate prediction has been identified. In objective 3 the costs incurred after implementing IoT solutions and before implementing IoT solutions have been obtained from the sources where IoT based system have been used. The cost benefits of using an IoT solution have been analyzed. In objective 4, a business model framework for the IoT prototypes built has been suggested. This objective has been achieved using interviews from the experts in the field of IoT industry and from a customized IoT business model framework.

There has been gaps which were observed such as many researchers have focused on the development of the IoT solutions; hardly anyone has mentioned their strategy to convert the products made into value for customers. Even IoT has been seen as technology which is still in the process of innovation. Researchers are still exploring the potential of these IoT and have lesser focus on building a business models. And it has been observed that price concern of the customers is one of the barriers to the implementation of IoT. But there are hardly any studies which have compared the costs and benefits of IoT solutions with traditional methods. And also Machine learning techniques such as MST, ANN, AR and SVM have not been used to predict drought ahead of time in agricultural lands.

1. Literature Review

IoT will be the cause of extreme business transformation in the coming three years according to a current KPMG survey of 750 tech leaders (KPMG, 2018). IoT has capability to create new value to the customers ,hence disrupting the existing business models.New models of business have to be created for new solutions of IoT.And specially when it the case of innovation,IoT can cause disruption and conventional business model canvas cannot support IoT characteristics to be properly replicated **(Hussam & Presser, 2018)** .According to a survey,46% of respondents that there will be transformation in the existing business model,30% have faith that IoT can open fresh income chances from the current product and services and 29% believe IoT will motivate new business processess **(Wnuk & Murari, 2016).** No proper tools are present to capture the complexity of IoT business models.Tools presented by Osterwalder and Pigneur are used, but are not effective for IoT business models. A problem to be addressed from a perspective of IoT stakeholder is to generate value. Value can be new experience, businesses, or return on investments (ROI) varying with respect to the stakeholder. The participation of many participants in the IoT digital value chain can create complicated business models necessary for many IoT applications **(Vermesan, Bahr, & Gluhak, 2011)**

The applications of IoT range from HR, banking, marketing to Finance and many more. It is essential for HR to appreciate the consequence of people analytics that comes from IoT. Internet of Things would generate huge volume of data related with individuals and their related processes. The data is widely helpful for decision and strategy makers. Trackers make it easier to monitor staff and to keep in check their actions without stressing too much. **(empxtrack, n.d.)** HR managers can spend less time in identifying a potential candidate for an interview.

By means of IoT solutions, financial institutions get actual data on their assets and customers' assets helpful in effective risk management. Through telematics, from vehicle insurance to house owner's insurance, telematics measures with the help of sensors, the usage of a thing and helps in forecasting and also measures the losses in the event where a client must file an insurance claim **(Group, n.d.).**

Understanding a customer's behaviour, buying patterns, and place also provides a level of attribution, analytics, and predictive abilities that were not present at first. Through the signals from IoT devices, timely notifications can be sent to consumers when they need to buy something, instead of waiting for them to show interest and this will be helpful in improving digital marketing **(Gainey, 2018).**

With the help of IoT technologies, business processes such as shipping and receiving can be linked with human, data and things such as containers, transportation trolleys to make supply chain management at maximum efficiency **(Chona, 2017).**

With RFID [2] and IIoT (Industrial internet of things), managers of inventory don't need to waste time on tracking manually and recording. Each thing is followed and the data about it is logged to a big data warehouse with manual help. With the help of the data generated, which is the inventory quantity and location. We can predict the volume of raw material necessary for the upcoming production cycle using machine learning **(Shiklo, n.d.).**

Street lighting usually uses lamps called HPS [3] which consumer more electricity. 70% of energy is created by fossil fuels which lead to air pollution, and globally there are around 300 million street lights utilizing this energy which results in huge expenses. Studies prove that proper street lighting can greatly decrease fatalities and accidents with pedestrians **(Sullivan & Flannagan, 1999)**. **Bullough & Rea, (2009)** had proved in another study that lighted junctions and highways have lesser accidents than not lighted areas. The present street light system is based on manual operation; the light is switched ON in the evening and switched OFF in the morning and these results in wastage of energy. This street light system exhibits issues like incompetence, energy consumption and additional maintenance problems. Defective lights can also be a cause for wrong doings on roads **(Rajesh, Antony, Jose, & Kumar, 2018).**

Soujanya, (2018) has made an automatic system of street lighting using 'Raspberry pi'. The focus is to switch ON light when human arrives inside a radius, and the light is OFF when it's not necessary. The communication is made through "Lora" wireless module, SPI and I2C communication is used. LED light is the most efficient light module. This technique uses two sensors; they are Ultrasonic sensor on the transmitter side and Lidar Lite V3 sensor on the receiver side.

Fujii, Yoshiura, & Takita, (2013) had made the lighting system consisting of power-adjustable LED array, brightness sensor, motion sensor, ZigBee module, and controller. It switches ON when movement is sensed by the sensor. It sends message to other units through ZigBee module when motion is detected. The sensor unit is put in many places, such as at electric poles, at house gates, to make sure that every street light turns ON before person notices that.

Ramli & Yamin, 2015 have made an automation system of street light using Arduino. LED is the light module. This system uses two sensors which are LDR[4] and Passive Infrared PIR sensor. This system can spontaneously turn on and off the lights according to the flow of traffic.

The water necessity in irrigation is large; there is a requirement for a SIS [5] that can prevent wastage of about 80% of the water. As technology is progressing, there is always an option of decreasing risks and making effort easier.

Darshana, Sangavi, & Mohan, (2015) have stated that implementation of IoT helps control water system by means of a sensor and micro controller system. By setting sensors in the region to monitor the soil temperature and moisture and further transmit the information to microcontroller for prediction of water requirements of plants.

Knowing the exact volume of water required by various plants in a given set of weather-related condition of an area is of great benefit in planning of irrigation scheme, scheduling, design and management of irrigation system which can be achieved by irrigation controllers. **Roy & Ansari, (2014),** had stated that a PLC based irrigation system has been used along with soil moisture sensor, water level sensor and GSM controller. Climatological inputs such as temperature, total radiation and total wind are measured by PLCs which then adjust the irrigation schedule to the observed inputs, leads to a reasonable saving in water.

In this study, the irrigation system can start or stop water pump based soil moisture input from moisture sensor and the water level in the reservoir from the ultrasonic sensor and these sensor values reported to Arduino microcontroller.

In the given study, the key objective is to keep in check, the moisture content of the soil through moisture sensor and measure the relative humidity, and irrigate depending upon the nature

[2] RFID (radio-frequency identification)

[3] (HPS)High Pressure Sodium lamps

[4] Passive Infrared (PIR)

[5] smart irrigation system(SIS)

using a PC based Lab VIEW system, NI my RIO, IoT, GSM and an automatic water inlet setup which can also monitor and record temperature, humidity and sunlight which get modified and can be controlled, so that yield is optimized. A record of these inputs are maintained which is useful in prediction of weather and helps the farmers in cultivating a type of crop in future **(Kumar, Gopal, & Sridhar, 2018).**

Buildings are significant infrastructures which support humans and contribute a significant part of energy usage. According to the yearly energy review of U.S in 2016, residential and commercial buildings use 40% of energy and 70% of electricity **(Zhao, Xia, & Jiang, 2018).**

In this study, they have checked and received the energy consumption data of buildings for a year and identified the consumption patterns and obtained results to improve efficiency. They have proposed a framework with smart location-based automated & networked energy control. They have utilized technologies like cloud computing, smart phone platform to allow multi-scale proportionality along with building, user and organizational proportionality. They have also created an IoT network and control system prototype and experimented it in real time to see the effectiveness of the proposed solution **(Pan, Jain, & Paul, 2015).**

In this study, the design and application of smart building prototype has been addressed. The building parameters have been collected by sensors and transferred to databases. These data are accessed, analysed and visualized. The key objective is to make the building settings suitable for the residents needs and so, environment properties such as temperature, light are controlled using model based controller **(Eini, Linkous, & Zohrabi, 2019).**

It is expected that IoT will by 2025, internationally create 90 zettabytes of data. This data is processed by sensors to cloud to store, analyse and visualize this data to make insights to progress operational efficiencies **(Torchia & Shirer, 2019).**As stated by EY,the use of sensors will lead to unbiased data about the world surrounding us. It is said that use of technologies like ML, deep learning or AI on a huge storage of data of IoT devices may be used to extract insights which will be helpful in decision making **(FutureIoT editors, 2019).** As number of devices connected through IoT will increase ,so along with it the data generated by the IoT applications will also increase which makes dealing with "Big Data "as common aspect. Big data can't be mantained using conventional databases. Special infrastructure and methods are required to analyze them . Many ML algorithms like ANN can deal with data effectively **(Zantalis, Koulouras, Karabetsos, & Kandris, 2019).**

In a research study ,a IoT based smart water quality monitoring system has been developed in which big data was generated in high speeds making it difficult to manage .They have used the techniques of *long short-term memory* (LSTM)[6] deep neural networks and designed a water quality model which can foresee the water quality from the big data **(Liu, Wang, Sangaiah, Xie, & Yin, 2019).**

In a study, the purpose was to review ML tecniques and IoT applications in Intelligent transportation System which gives a clarity of trends in given field .From the literature reviewed in the study it is clear that there is less ML attention for Smart lighting and parking (**Zantalis, Koulouras, Karabetsos, & Kandris, 2019). Nilsson, (n.d.)** explains that when a machine is given different kinds of inputs which brings change in its structure, then the machine learns and progresses its performance in future. An addition of samples of speech improves the recognition capability of the device, and hence we can say that the machine has learned.

3. Analysis & Findings

MACHINE LEARNING TECHNIQUES FOR FORECASTING TIME-SERIES DATA

A Machine learns when its structure, program or data changes and improves its performance in future. It executes tasks related with Artificial Intelligence. Its tasks include recognition, planning,

[6] *long short-term memory* (LSTM)

robot control, forecasting etc. The first question is that why should a machine learn in the first place; why can't it be designed to perform the wanted job. For some tasks it's not easy to depict relationships between input and output. So the systems are needed to modify their structure in order to give the required outputs. Among the large amounts of data are relationships and correlations between the data and the machine learning useful in extracting this data. The following machine learning techniques have been used while dealing with a time series data:

MST is graph which has its edges weighted and is acyclic which means any two vertices have only one path of connection. These networks are constructed using Prim's or Kruskal's algorithm. The total edge- weight of the graph in these algorithms is as minimum as possible.

The problem faced while dealing with complex networks is that it has too many interconnections. If there are m nodes i.e. there are m villages then there are m^2 connections and makes the network crowded and hard to comprehend and analyze. To deal with this kind of problem Link Reduction Algorithms is helpful in keeping the useful information and removing the information which is not useful. MST is a type of link reduction algorithms.

MST gives network of m-1 interconnections which is helpful to understand easily and extract information.

AR Model

These are Univariate time-series models which have the dependent variable as a weighted linear combination of past data assuming that the previous data is helpful in estimating future.

The weightage of the data depends on the how much past the data is i.e. more past the data is lesser weightage is given to it.

$$S_t = \psi + \varphi_1 S_{t-1} + \varphi_2 S_{t-2} + \varphi_3 S_{t-3} + \varphi_4 S_{t-4} + \varphi_5 S_{t-5} + \cdots$$

S_t is dependent variable at time t,

ψ refers to the constant term

S_{t-i} is the past t – i observations,

φ_i is the weights with respect to $S_{t-I,}$

ν_t is the error term.

These AR models can be estimated by various methods but in the study, Maximum Likelihood method of estimation has been utilized with different lag structures

AR (1) model - $S_t = \psi + \varphi_1 S_{t-1} + \nu_t$

AR (2) model - $S_t = \psi + \varphi_1 S_{t-1} + \varphi_2 S_{t-2} + \nu_t$

AR (3) model - $S_t = \psi + \varphi_1 S_{t-1} + \varphi_2 S_{t-2} + \varphi_3 S_{t-3} + \nu_t$

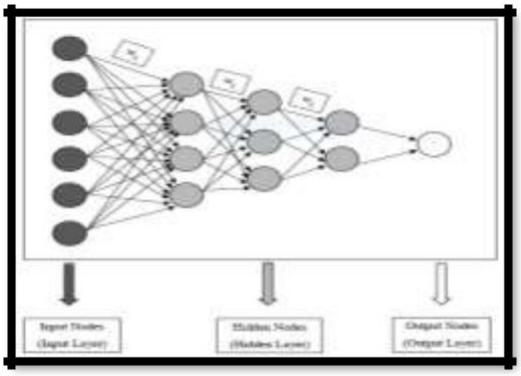
AR (4) model - $S_t = \psi + \varphi_1 S_{t-1} + \varphi_2 S_{t-2} + \varphi_3 S_{t-3} + \varphi_4 S_{t-4} + \nu_t$

The models are compared and the better model is found based on accuracy.

An ANN is system of artificial intelligence which works like a human nervous system. Its layers consist of input, hidden and output layer and every layer has many number of neurons. The information is given in the input layer and further processed to hidden layer for processing. This data is processed and further gives the output. As the data is being fed, weights are assigned to the edges connecting the neurons. The weighted sum of the input information is transformed using activation function and further transferred to next layers and finally passed to the output layer in order which is well defined, to deliver the final output. The activation function can be any mathematical function which is well defined.

The neural networks have to be trained, so that they can forecast. Higher the number of hidden layers, higher is the degree of accuracy.

Figure An Artificial Neural Network

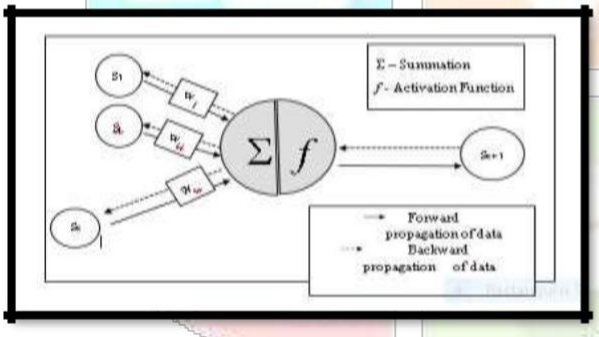


Source: Self-Generated

Back propagation neural networks

In these neural networks the connections are recurrent and the flow of information is bidirectional. And is helpful in modification of weights in order to obtain a better model and least error. Weights are assigned from the output to the input nodes and adjusted to get the minimum error when information flows from the input to the output.

Figure: Back propagation neural network



Source: Self-compiled

Another categorization can be based on number of hidden layers i.e. if only one hidden layer then it is called single-layer perceptron model else it is called multi-layer perceptron.

ADVANTAGES OF NEURAL NETWORKS

The data of different types and properties can be used on ANN. ANN has the capability to learn and identify patterns in the complicated non-linear data sets. ANN can manage data with missing values.

DISADVANTAGES OF NEURAL NETWORKS

ANN consume lots of time in training data. The hidden layer is a black box from where nothing can be collected. Data used for training should be of high quality. Skill is required to operate ANN. It cannot be used for tiny datasets.

SVM

SVMs are models and algorithms useful in classification and regression analysis. If the training set is made to belong to one or other category, then these training set build an algorithm that builds a model which allots the new observation in one or other category making it a probabilistic binary linear classifier. SVM model represents points in space, presented in such a manner that it distinguishes the observations by a clear gap. The new observations are mapped in the space and forecasted to fit to a group depending upon the side of the gap on which they fall.

SVM's can also perform on non-linear classification using kernel trick. SVM is preferred as it provides accuracy with less computation power. SVM's can be used for both categorization and regression.

The equation for creating a estimation for a new input using the dot product between the input (x) and each support vector (xi) is found as follows: f(x) = B0 + sum(ai * (x,xi))

Inner product of new input vector (x) with support vector (xi) in training data.

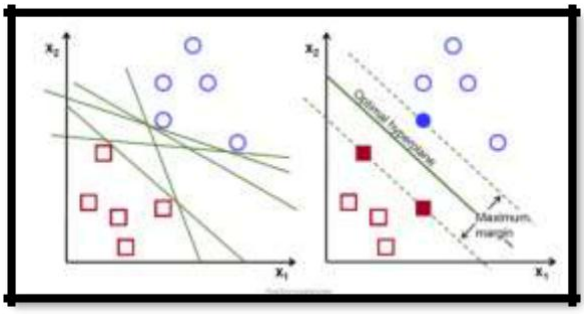
The coefficients B0 and ai (for each input) must be predicted from the trained data through the learning algorithm.

LINEAR KERNEL SVM

In the above equation f(x) = B0 + sum (ai * (x, xi)). The dot product is called kernel, can be written as K (x, xi) = sum (x * xi)

This kernel gives the similarity and distance measurement between the new input and support vector as the distance is a linear combo of inputs.

Figure : Classifying Data Through SVM



To categorize data, hyperplanes must be chosen. A hyperplane must be chosen in such manner that it has maximum margin which is maximum distance between data of both classes.

Complex Kernels allow the lines to distinguish complex classes and lead to more accurate classifiers.

METHODOLOGY FOR ACHIEVING THE OBJECTIVES

The following discussion deals in detail with the methodology followed for achieving each of objectives set for the study

A SIS[7] is a sensor-based irrigation system that irrigates the land whenever the moisture content falls below the required threshold value. This system has been assembled using the hardware components described. The hardware parts have been assembled according to the system design depicted in the chapter 5. The Arduino has been programmed using C language.

After the prototype has been built, it has been tested on 2 pots, one is Pot 0 and the other one is Pot 1. Pot 0 has soil from the drought land whereas the Pot 1 has soil from the cultivatable land. After testing the prototype, the real-time parameters in the environment, such as moisture in the soil, temperature, & humidity in the environment have been collected using moisture content sensor and DHT sensor. The data collected can be accessed and stored in the cloud called Think Speak.

ASLS is a lighting system which switches ON and Switches OFF depending on the movement. ASLS uses PIR and LDR sensor. This system has been made using the hardware parts described in the chapter 5. The hardware parts have been assembled according to the system design depicted in the chapter 5. The Arduino has been programmed using C language.

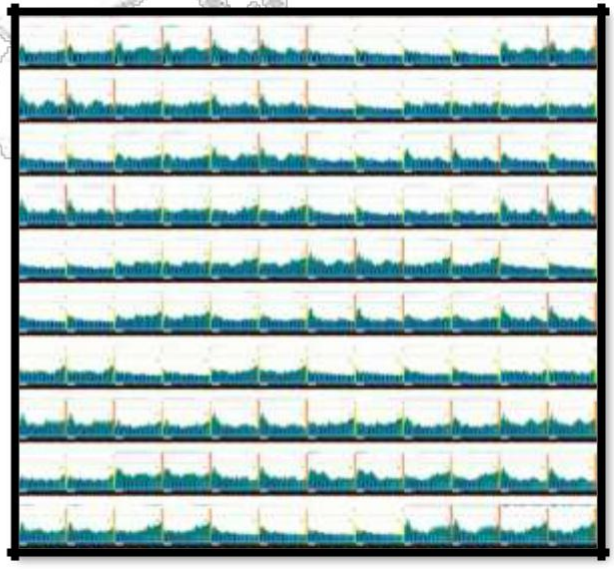
The prototype was implemented on the streets for 2 days to test its working. The sensors present in the system gave updates of various real-time parameters around the system such as Switch OFF/ON status, temperature, and light intensity. The system was connected to a cloud called Think Speak where these data were stored and visualized.

A Voice-controlled home automation system which uses speech to text to convert speech information into text. This system can switch ON or OFF the bulb, fans, AC, Fridges, and other electronic appliances through voice instructions.

This system has been made using the hardware parts described. The hardware parts have been assembled according to the system design depicted. The Arduino has been programmed using Python

Data used in the study for voice controlled home automation. The 100 voice samples of Switch In and Switch Off have been taken respectively, and the percentage of recognition for different sample sets 10, 20 ,30, 40, 50, 60, 70, 80, 90 and 100 have been calculated for both Switch In and Switch Off.

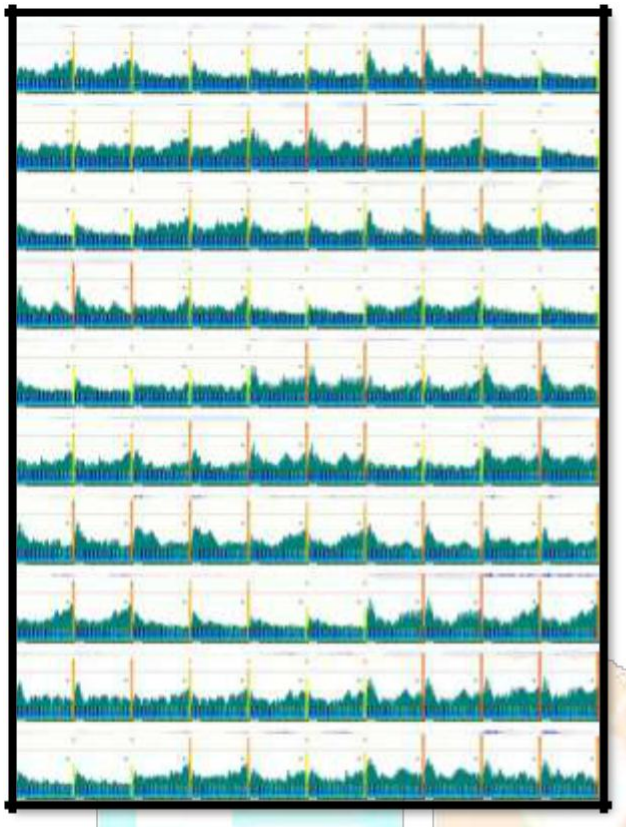
Figure: "Switch In" 100 Voice Samples"



Source:Self made

Figure: "Switch Off" of 100 Voice Samples

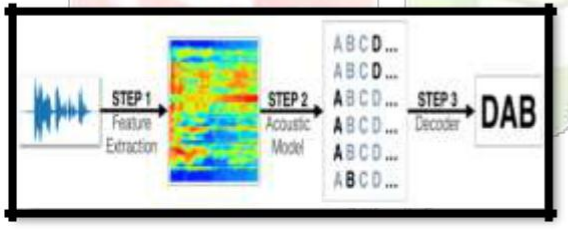
[7] Smart irrigation system (SIS)



Source: Self- Generated

Using the voice samples data to evaluate the recognition ability of the design

Figure: Process followed in converting speech to text



Source: Self-made

Stages of the Voice controlled Home automation system for evaluating the recognition

Ability of design.

Step 1 A numerical data set of voice samples of Switch IN and Switch OFF has been made. The numerical words of the dataset save time and help in the extraction of features in the voice of the person.

Data set for numeric words

Switch IN is '0'

Switch OFF is '1'

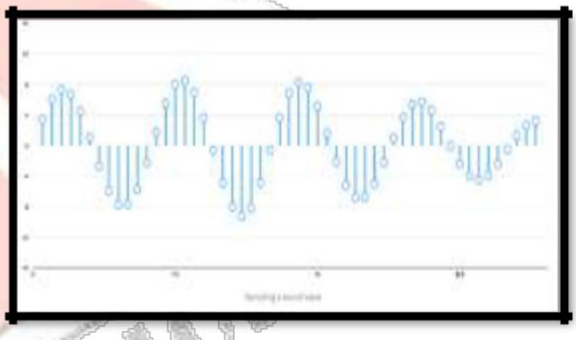
Step 2 'Switch In' and 'Switch Off" set have to be recorded

The samples are recorded through the Mic which is connected to the working system which is a laptop. The samples are recorded through Mat lab function "Wave Record", which records through PC based input. The recording has been done for 2 secs, a sampling rate of 44100 Hz.

Turning sound waves into numbers

The sound is communicated in the form of waves. These waves have t depicted in the form of numbers. These waves have single value accor to height of the wave at that point of time. The height of the wav uniformly distributed points is recorded and this process is called sampli

Figure: Converting waves into numbers



Source: Medium

The rate of sampling is 44100 Hz, which is 44100 samples per 2 second and is sufficient to cover the frequency of human voice.

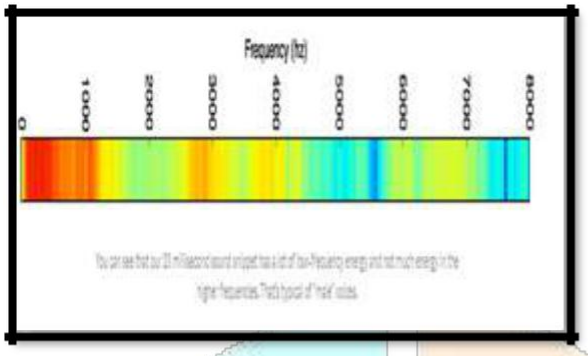
Step 3 Feature Extraction

Around 30 speeches are recorded in different expression by both male female. The numerical words were allotted for this purpose. A recording, the speeches are selected to change the vector into a matrix f through "vec2mat" function Example: of converting vector in matrix for

These numbers are fed into neural network. But directly processing the samples is hard to recognize the voice patterns. The voice data can be pre-processed to make the process easier. The voice data can be grouped into 20-millisecond portions. This is $1/50^{th}$ part of a second-long recording. But such short part of a recording has variations in frequencies of the voice. These variations in frequencies make a human speech. To make this

complex sound wave easier to process for the neural networks, these sound waves are broken into components such as low pitched, next lowest pitched and so on etc. Depending upon the energy in each of these components a fingerprint of sorts is created and this is done through Fourier transform.

Figure: Spectrogram sound snippet



Source: Medium

The process is repeated for next chunks of 20 millisecond of the sound which will lead to spectrogram. Neural network can recognize patterns in these kinds of data compared to sound waves. This data is fed into neural networks. The neural network will relate the alphabet concerning the sound.

Step 4 Analyzing & evaluating the training.

This step provides the decision logic part of the project i.e. a model has been made which can make voice recognition better.

Step 5 The system is evaluated with respect to the Testing set.

The Neural network which is trained with 70 samples during the training phase and was tested with 30 samples in the testing phase. The testing should take place in a soundproof place.

Step 6 Analyze the recognition results.

The results are analyzed in the next chapter which is the Empirical Analysis. Turning sound waves into numbers, the sound is communicated in the form of waves. These waves have to be depicted in the form of

that point of time. The height of the wave at uniformly distributed points is recorded and is called sampling.

Data Required for the Study

Analyzing and forecasting the moisture in soil using the data provided by the sensors early identification of the possibility of drought in the villages.

The data focused in the study is time series data. As the moisture content measured is variable which measures at regular intervals of time. So the data is univariate continuous time series data**.**

Time Series data

The measurements measured in time series are arranged in sequential order. A time series having only one variable is called as univariate whereas if it contains many variables is called multivariate. If the series are measured at every instant is called" *continuous time series*" whereas if measured at different points of time are called "*discrete time series"*.

A time series data usually gets influenced by 4 things: "*Trend*, *Cyclical*, *Seasonal* and *Irregular"*. The past data is collected and analyzed and developed into a mathematical model, which is helpful in forecasting the future. Many times decisions and precautionary measures are done depending on the forecasted results.

The moisture content data has been taken from their respective soils. The variety planted in the soils has been mentioned in the table. The data is a real time data and also is a time series data.

Table: Villages with the crop variety sown

SL No	Division	Mandal	Village	Variety
C1	VIZIANAGRAM	VZM-1	KONDAKARAKAM	MTU 1121
C2	GAJAPATHINAGARAM	MENTADA-5	LAXMIPURAM	RGL2532
C3	CHEEPURUPALLI	Gurla -2	THATIPUDI	MTU1001
C4	BOBBILI	Therlam -2	Kusumuru	MTU1156

C5	SALURU	Saluru-3	ANTIVALASA	LRG-41
C6	SALURU	Pachipenta -3	Viswanadapura M	LRG41
C7	PARVATHIPURAM	Garugubilli-5	SIVVAM	MTU1121
C8	G.L.PURAM	Jiyyammavalasa-4	LAXMIPURAM	MTU1064
D1	KOTHAVALASA	JAMI-4	CHINTHADA	MTU1121
D2	KOTHAVALASA	SKOTA-2	SANTHAGYRAMMAPETA	MTU1121
D3	KOTHAVALASA	LKOTA-5	MUTYAMMAPALEM	MTU1156
D4	GAJAPATHINAGARAM	MENTADA-5	PEDAMEDAPALLI	k6
D5	GAJAPATHINAGARAM	DATTIRAJERU-3	KRISHNAPURAM	K6
D6	G.L.PURAM	G.L.Puram-3	Manda	REDGRAM
D7	G.L.PURAM	G.L.Puram-3	THADIKONDA	REDGRAM

Source: Self-compiled (Collected from 15 villages)

Data classification based on stages

The observations of moisture content are made for 3 stages which are vegetative, reproductive and ripening. From each village a total of 2880 moisture content data has been taken. And these 2880 observations have been divided into 3 phases in the following manner depicted in the table**.**

Table: Data classification based on stages

Phase No.	Time Division	No. of Observations	Phase Description
1	01-07-2018 to 01-09-2018	1440	Vegetative
2	01-09-2018 to 01-10-2018	720	Reproductive
3	01-10-2018 to 01-11-2018	720	Ripening
4	01-07-2018 to 01-11-2018	2881	Entire time period

Source: Self-compiled (Collected from 15 villages)

There are 4 stages involved in the growth of paddy which is sapling, vegetative, reproductive and ripening. Less amount of water is required during the sapling stage, but during transplantation a depth 2 cm is needed for 7 days followed by 5cm is required for development of roots and same level is required for shoot development in vegetative phase. During the flowering phase 5cm submergence is needed. And at ripening stage less water is required and can be slowly drained from the area, 15-21 days prior to harvesting.

Whereas groundnut and red gram need only 500-550mm of water level. Evaporation and transpiration is minimum during the first 35 days after sowing and last 35 days before reaping but is maximum during the peg penetration and pod development. After seeding, watering can be scheduled after 25 days which is 4 to 6 days after digging and a watering interval of 15 days is required until flowering.

Vegetative stage: Submergence of 5cm is needed after seeding to prevent damage to deeds due to winds followed by 2cm submergence for tiller growth and root formation. Moisture stress may result in decrease in yield by 30%.

Reproductive stage: Moisture stress at this stage may result in yield loss of about 50-60%.

Harvesting stage: No necessity for water and water can be drained from the area 7-10 days before harvest.

Training and forecasting observations

The 70% of 2880 observations are used for training; whereas 30 % of data is used for forecasting.

Table: The table depicts the division of observations at different phases and also shows the time period of the observations w.r.t to villages.

Source: Self-compiled (Collected from 15 villages)

Village Id No.	1st Spell	2nd Spell	3rd Spell	Phase 1	Phase 2	Phase 3
C1	18-7-18	9/10/2018	2/11/2018	1440	720	720
C2	26-07-18	25-09-18	14-11-18	1440	720	720
C3	2/7/2018	30-08-18	30-1018	1440	720	720
C4	18-07-18	16-10-18	28-11-18	1440	720	720
C5	26-07-18	4/9/2018	31-10-18	1440	720	720
C6	18-07-18	11/9/2018	13-11-18	1440	720	720
C7	13-07-18	14-09-18	5/11/2018	1440	720	720
C8	20-06-18	28-09-18	9/11/2018	1440	720	720
D1	20-06-18	25-09-18	Drought	1440	720	720
D2	21-06-18	26-09-18	Drought	1440	720	720
D3	19-06-18	4/10/2018	Drought	1440	720	720
D4	22-06-18	31-08-18	31-10-18	1440	720	720
D5	23-06-18	12/9/2018	21-11-18	1440	720	720
D6	6/7/2018	12/9/2018	1/11/2018	1440	720	720
D7	13-06-18	11/9/2018	3/11/2018	1440	720	720

METHODOLOGY USE FOR ANALYZING AND FORECASTING MOISTURE

Analyzing and forecasting the moisture in soil using the data provided by the sensors for early identification of the possibility of drought in the villages.

Understanding the network topology of agricultural lands based on moisture content data using minimum spanning tree for early identification of drought in villages.

Minimum Spanning Tree Network

With the increase in climate variations can increase the possibility of climate extremes. This will change the scale, period and frequency of natural disasters. Among these natural disasters, droughts disturb people the most. Droughts may change according to sector and region, and continue for months together, during droughts rainfall is lesser than the average which leads to water scarcity.

If the network appears in the form of star, then it represents robustness. Robustness means the system's ability to cooperate with disturbances. But if the system appears chain-like it will show reduction in irrigation of water.

The correlation between the sectors is depicted in the network. If there is star structure, this shows that one village is highly correlated to others. But if only chain is formed, it means that villages are independently connected to each other.

Step 1: Cross-correlation existing between the villages. The growth rates of moisture content of the villages are utilized to find out the cross-correlation matrix amongst the villages. These cross correlations are made separately for 3 stages and also for entire duration, using the data.

Table: Number of observations collected in the given time period for the given phase

Phase No.	Time Division	No. of Observations	Phase Description
1	01-07-2018 to 01-09-2018	1440	Vegetative
2	01-09-2018 to 01-10-2018	720	Reproductive
3	01-10-2018 to 01-11-2018	720	Ripening
4	01-07-2018 to 01-11-2018	2881	Entire time period

Source: Self-compiled (Collected from 15 villages)

The cross-correlation formula

$$c_{ij} = \frac{E\left[(i - E(i))(j - E(j))\right]}{\sqrt{E(i - E(i))^2}\sqrt{E(j - E(j))^2}}$$

c_{ij} is the cross correlation among villages i and j
E(i) and E(j) is the expected value (growth rate of moisture content) of i and j.

Step2: Distance Calculation among the villages

The distance among the villages is used to build the network, which is calculated using cross-correlations among them. This step takes place after the cross – correlations among the villages

have been obtained. Higher is the cross correlation among the villages lesser is the distance between the villages in the network.

$$d_{ij} = \sqrt{2(1 - c_{ij})}$$

d_{ij} is the distance among villages i & j

c_{ij} is the cross-correlation among villages i & j.

Step 3: Constructing the network using MST

MST is used to create network between the 15 villages, in order to understand the change in network topology of the agricultural lands, during the various stages.

MST is graphs whose edges are weighted, and acyclic in nature which means any two vertices have only path of connection. These networks are constructed using Prim's or Kruskal's algorithm. The total edge-weight of the graph in these algorithms as minimum. This study uses prim's algorithm to build a MST for the villages at different stages. MST is generated through igraph package in R software. The procedure to construct a MST using Prim's algorithm is given below.

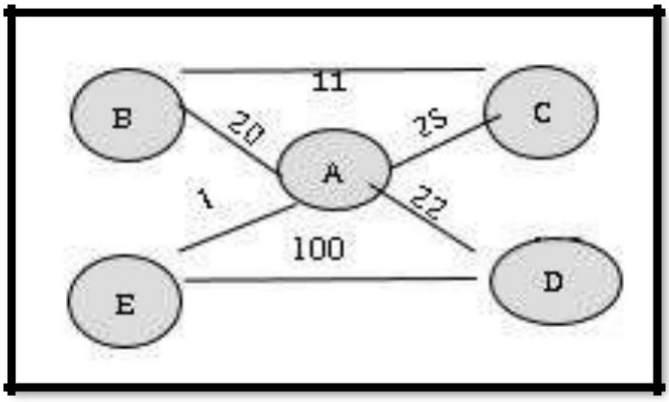
The minimum spanning tree are drawn from the following graph

There are 2 groups J& K in which the nodes are divided. Initially the graph is started with an empty graph. Each node can be grouped in either of the group or grouped in both the groups. Any arbitrary node say node A has been included in set J and removed from set K. The minimum weight is between the E and A. E has been included in set J and removed from set K. After the connection between E and A, the least weight is between A and B.B has to be included in set J and removed from set K.

Similarly, the steps have been repeated until all elements in set J are empty. Whenever the height is same the MST's of either of the path has to be chosen.

The minimum spanning tree is drawn from the following graph

Figure: Prim's Algorithm



Source: Self -compiled

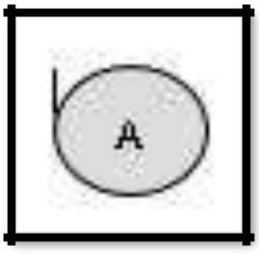
There are 2 groups J& K in which the nodes are divided. Initially, the graph is started with an empty graph. Each node can be grouped in either of the group or grouped in both groups.

Table: Nodes Division through Prim's Algorithm

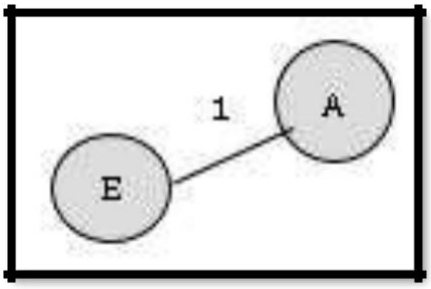
Step No.	*Nodes included in set J*	*Nodes remaining in set K*
0	*( )*	*(A, B, C, D, E)*
1	*(A)*	*(B, C, D, E)*
2	*(A, E)*	*(B, C, D)*
3	*(A, E, B)*	*(C, D)*
4	*(A, B, E, C)*	*(D)*
5	*(A, B, C, D, E)*	*( )*

Source: Self made

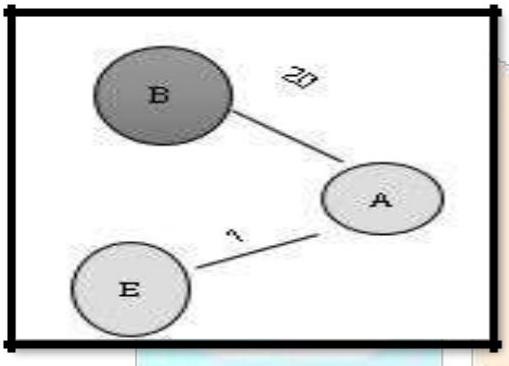
Step-1 Any arbitrary node say node A has been included in set J and removed from set K.



Step-2 The minimum weight is between the E and A. E has been included in set J and removed from the set K

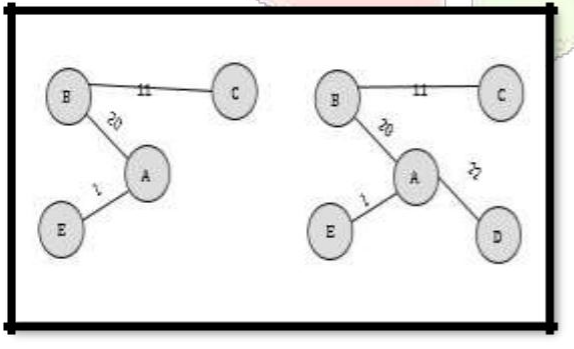


Step-3 After the connection between E and A, the least weight is between A and B.B has to be included in set J and removed from set K.



Source: Self-mode

Similarly, the steps have been repeated until all elements in set J are empty. Whenever the height is same the MST's of either of the path has to be chosen.



Source: Self-compiled

ADVANTAGES OF MST

The problem faced while dealing with complex networks is that it has too many interconnections. If there are m nodes i.e. there are m villages then there are m^2 Connections and makes the network crowded and difficult to understand and analyse. To deal with this kind of problem Link Reduction Algorithms helps keep useful information and remove the information which is not useful. MST is a type of link reduction algorithm.

MST gives the network of m-1 interconnections which is helpful to understand easily and extract information.

In-Sample Forecasting

Using the moisture content data of 15 villages generated from the sensors, identifying the optimum forecasting model out of ANN, SVM and AR models, which can forecast the moisture content data with maximum accuracy and minimum error.

The techniques used to forecast the moisture content data are Autoregressive models, Artificial Neural Networks, Support Vector Machine.

Techniques used in forecasting

The following machine learning techniques have been used in In-sampling forecasting.

Usually while practically implementing a data, a data consists of both linear and non-linear components**.** Only single model cannot identify all the features of data.AR has capability to model different types of time series but AR cannot be applied to small data sets. The accuracy of SVM and ANN depends on their value of parameter. So in order to get through this problem, SVM and ANN are trained based on AR models of lag length which is helpful in estimating the parameters of SVM, ANN. The time series models use historic data to forecast the future which can be classified into linear (AR) and nonlinear models (ANN). Usually time series data require large number of data. But the current study has insufficient data of village which makes it less suitable for forecasting of moisture. Therefore, there is a necessity for a model which will be suitable for small data sets. These models can be used for both linear and nonlinear data sets.

AUTOREGESSIVE MODEL (AR)

These are univariate time-series models which have the dependent variable as a weighted linear combination of past data assuming that the previous data is helpful in estimating future.

The weightage of the data depends on the how much past the data is i.e. more past the data is lesser weightage is given to it.

$$"S_t = \psi + \varphi_1 S_{t-1} + \varphi_2 S_{t-2} + \varphi_3 S_{t-3} + \varphi_4 S_{t-4} + \varphi_5 S_{t-5} + \cdots + \varphi_z S_{t-z} + v_t"$$

S_t is dependent variable at time t,

ψ refers to the constant term

S_{t-i} is the past t – i observations,

φ_i is the weights with respect to to S_{t-i},

v_t is the error term.

These AR models can be estimated by various methods but in the study, Maximum Likelihood method of estimation has been utilized with different lag structures

$$"AR\ (1)\ model\ S_t = \psi + \varphi_1 S_{t-1} + v_t"$$

$$"AR\ (2)\ model\ S_t = \psi + \varphi_1 S_{t-1} + \varphi_2 S_{t-2} + v_t"$$

$$"AR\ (3)\ model\ S_t = \psi + \varphi_1 S_{t-1} + \varphi_2 S_{t-2} + \varphi_3 S_{t-3} + v_t"$$

$$"AR\ (4)\ model\ S_t = \psi + \varphi_1 S_{t-1} + \varphi_2 S_{t-2} + \varphi_3 S_{t-3} + \varphi_4 S_{t-4} + v_t"$$

The models are compared and the better model is found based on accuracy. These models are forecasted using FitAR in R software. The long-term forecasts tend to merge with mean of the data and this is the challenge of autoregressive models.

ANN for Forecasting

The data of different types and properties can be used on ANN.ANN have the capability to learn and identify patterns in the complicated non-linear data sets. ANN can manage data with missing values.

In this study we use a resilient back propagation with weight backtracking algorithm, and the activation function is tanh which is hyperbolic tangential function. It is a feedback neural network algorithm but is better than regular backpropagation algorithm. It is faster and requires lesser number of parameters. Weights are modified from the output node with each successive update in order ot reduce the error. The neural networks have to be trained, so that they can forecast. Higher the number of hidden layers, higher is the degree of accuracy.

In this study the package used is "neuralnet" and program language used is R programing.

The main parameter to be specified is the mathematical formula to be used for the training of the model. In this study, 4 AR models with lags varying from 1 to 4 have been used, in order to identify the best model among the set of models. The network architecture being, an input layer with nodes varying from 1 to 4 based on the lags of AR, the hidden layer made up of 8 layers consisting of the corresponding number of nodes (3, 5, 2, 7, 6, 8, 4, 1) in each layer, and one node in the output layer. The neural networks have to be trained, so that they can forecast. Higher the number of hidden layers, higher is the degree of accuracy.

SVM for forecasting

SVM are useful in classification and regression analysis. If the training set is made to belong to one or other category, then these training set build an algorithm that builds a model which allots the new observation in one or other category making it a "*probabilistic binary linear classifier*". SVM model represents points in space, presented in such a manner that it distinguishes the observations by a clear gap.

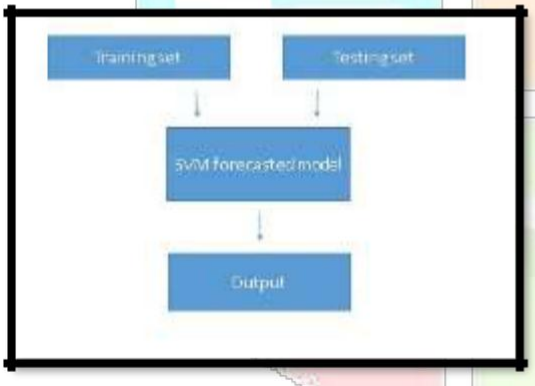
Complex Kernels allow the lines to distinguish complex classes and lead to more accurate classifiers. In this study the package used is called "e1071" in R programming. The data of the moisture content is loaded and split into training and tested set. The training set is 70% of the total set and the tested set is 30% of total set. The training size is cut to save time on training. The data is prepared and understood. The data is understood and prepared.

And a training model is developed. The hyper parameter tuning and cross validation done using train function in "Caret "package.

Forecasting Framework

The set of Data is divided into training and testing set. The training set is trained and learns to modify parameters for optimal values. The future value is forecasted after the machine learns completely. And also we get the optimum parameters C (penalty factor) and γ(kernel function parameter) through grid-search on C & γ with cross-validation. The forecasting is done and values are obtained after the test set is given to the trained SVM model. Only single point forecast is done every time i.e. only one output at every iteration. When the moisture content is forecasted, then the real value of the moisture content is put into training set in order to remodify the training set.

Figure: Forecasting Framework



SOURCE: SELF-COMPILED

Forecasting Ability of Various Models

It is used to evaluate the forecasting capability of the various models. The various forecasting models of SVM, AR and ANN have been assessed using this models. The actual value minus the estimated value is considered as forecasted error. The forecasted error and accuracy are inversely proportional. This is helpful in determining the models which are best suitable for predicting. After training the set, it has to be checked for its ability to forecast n steps ahead where n is total number of observations present in the testing test.

After the forecasts are found, the accurateness of the forecasts can be calculated using the formula –

$$v_t = S_t - F_t$$

v_t is the forecast error, *"S_t is the actual value at time t:" "F_t is the forecasted value at time t."*

Some of the frequently used measure of accuracy is

1) Mean Error = $_m\sum v$ =1

2) Mean Absolute Error = $_m\sum|v|$ =1

3) Mean Square Error = $_m\sum v^2$=1

4) Root Mean Square Error = $\frac{1}{m}\sqrt{\sum}$

"Mean Square Error (MSE) "[8]and "*Root Mean Square Error (RMSE)* "[9]are said to be better accurate methods, and hence, they are made use of in the study.

LIMITATIONS OF THE STUDY

The real time IoT applications have not been built, only its prototypes have been built which can be used in small scale implementation. The data used for forecasting was for a time span of 4 months and higher time horizon data is helpful in precise results. In objective 3 only operational costs have been taken because of the variability in cost of depreciation. Hence, depreciation costs have been ignored.

[8]Mean Square Error (MSE)

[9]Root Mean Square Error (RMSE)

EMPIRICAL ANALYSIS OF RESULTS

The empirical analysis of objectives has been mentioned in this chapter. In order to do the analysis different tools has been used. In objective 1 the prototypes built have generated data in the form of graphs.

The MST networks obtained at different phases have been analyzed and with the help of RMSE and MSE values the best model out ANN, AR and SVM has been found.

ANALYSIS OF OBJECTIVES

The results obtained after following the methodology has been analyzed.

To understand the processes of IoT solutions by building prototypes of IoT using the hardware components required, in the areas of street lights, irrigation and home automation and testing them.

This objective is achieved by the assembly of hardware component required to make the prototype and the microcontroller in the prototypes have to be programmed using languages like python and Matlab in order to give commands to perform the specific tasks. The prototypes were built on the basis of their respective system design. And the prototypes have been tested for their working.

Smart Irrigation System

Figure: Working of Smart irrigation system

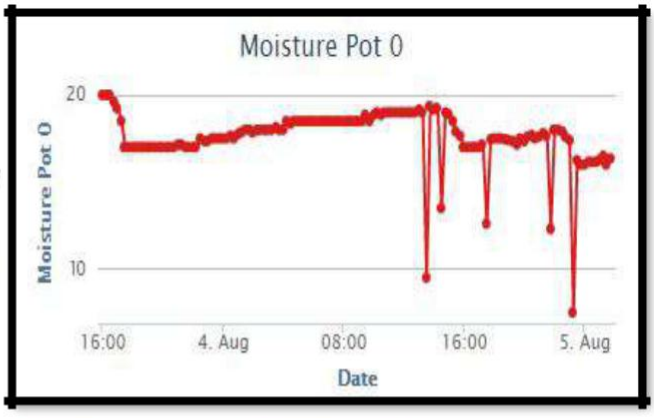
It is a sensor based irrigation system which irrigates the land whenever the moisture content falls below the required threshold value**.**

The prototype has been tested on 2 pots; one is Pot 0 and the other one Pot 1. Pot 0 has soil from the drought land whereas the Pot 1 has soil from the cultivatable land. After testing the prototype, the moisture, humidity and temperature sensor have updated the real time parameters in the environment, such as moisture content in the soil, temperature and humidity in the environment. The system has been stored in a cloud called Think Speak.

Data generated after implementation of Smart irrigation system.

Moisture Pot 0 represents a soil from Drought region whereas Moisture Pot 1 represents soil of a cultivatable land. The graph is plotted with the help of the data generated by the sensors.

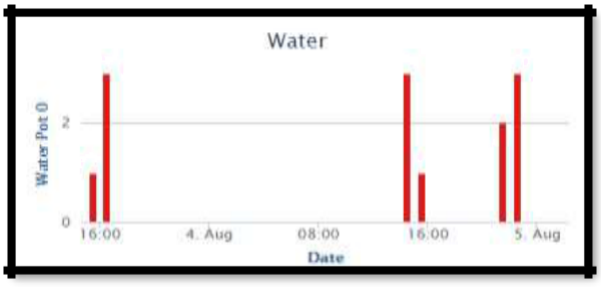
Figure: Moisture vs. Time graph



Source: Self – Generated

In the above graph the moisture content ranges from 0-20mm.The moisture content is reducing and increasing with respect to time. The moisture content range in the soil is low because it is Soil from the drought region.

Figure: Number of times and amount of water the pot has been irrigated according to the necessity of moisture content versus Time.

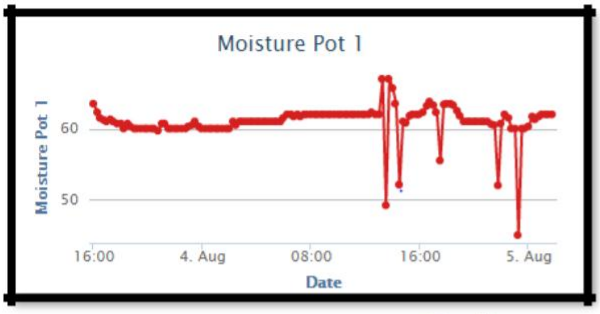


Source: Self – Generated

In this graph whenever moisture level is reducing, the Pot is irrigated .As we can see that in the Graph the respective time at

which the moisture level is reducing ,the the Pot is irrigated at that particular time in the graph. Enough water is irrigated whenever there is water deficiency in the soil.

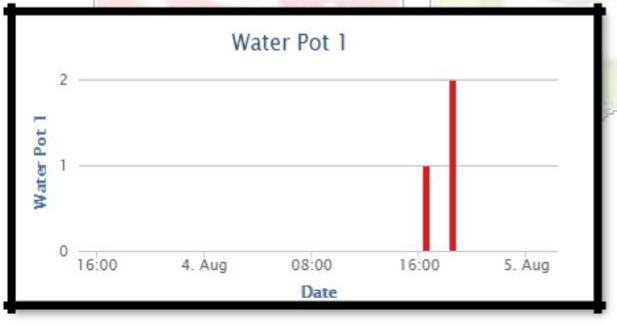
Figure: Moisture content in Pot 1 vs. Time



Source: Self – Generated

In the Pot 1 the moisture content ranges from 0-60mm or above. As the Pot contains the soil of a cultivatable land, so the moisture retention and requirement capacity of soil is more. The moisture content is increasing as well as decreasing at different intervals of time.

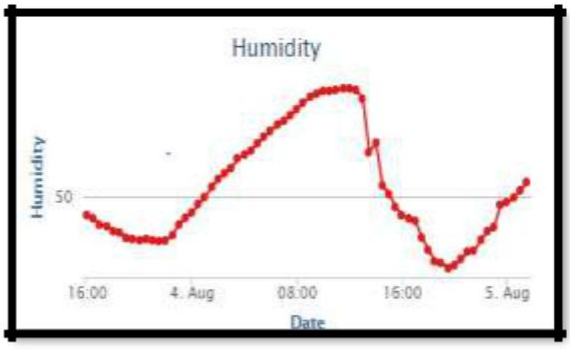
Figure: Number of times and the amount of water the Pot 1 is irrigated w.r.t to the necessity of the Moisture Content vs. Time



Source: Self – Generated

In this graph whenever moisture level is reducing ,the pot is irrigated .As we can see that in the Graph the respective time at which the moisture level is reducing ,the the Pot is irrigated at that particular time in the graph 6.5.Enough water is irrigated whenever there is water deficiency in the soil.As we can see that the number of times the soil is irrigated in cultivated land is lesser than the times the water irrigated in the soil of a drought region.

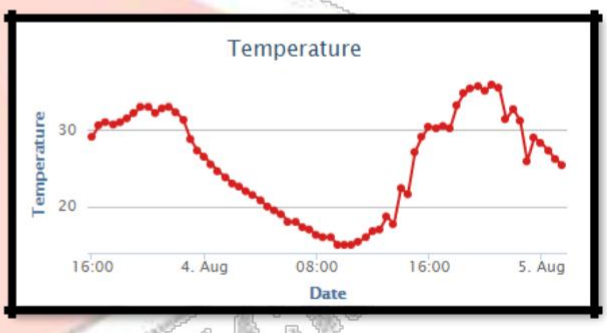
Figure: Humidity vs. Time



Source: Self – Generated

The humidity represents the amount of water present in the atmosphere. It is higher at the day time i.e. morning s and afternoon. The humidity decreases at evening and night.

Figure: Temperature vs. Time graph.



Source: Self – Generated

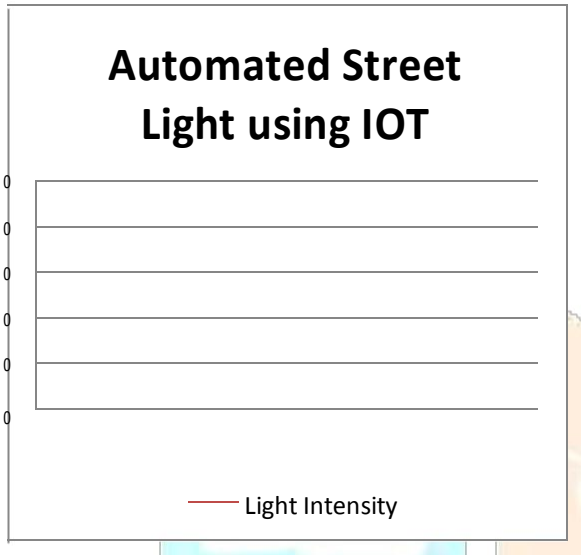
From the graph the temperature is gradually increasing from the morning and is in its peak in the afternoon and gradually reduces as the evening arrives. When the temperature is higher the moisture content in the soil reduces as there is higher amount of evaporation from the soil and it is necessary to irrigate water at that point of time.

Automated Street Light System

It is Sensor based lighting system which 'Switch ON' and 'Switch OFF' based on the movement. The prototype was implemented on the streets for 2 days to test its working. The sensors present in the system gave updates of various real time parameters around the system such as Switch OFF/ON status,

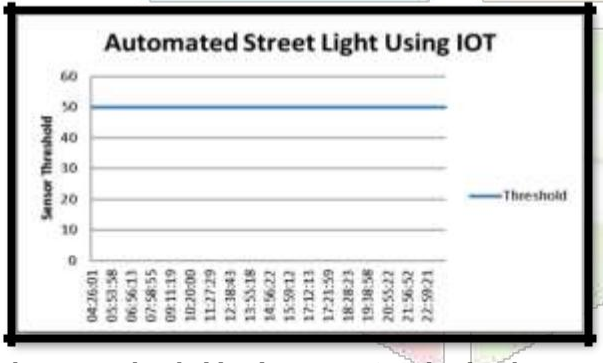
temperature and light intensity. The system was connected to a cloud called Think Speak where these data was stored and visualized.

The data of the light usage was stored in the SD card using the circuit made.



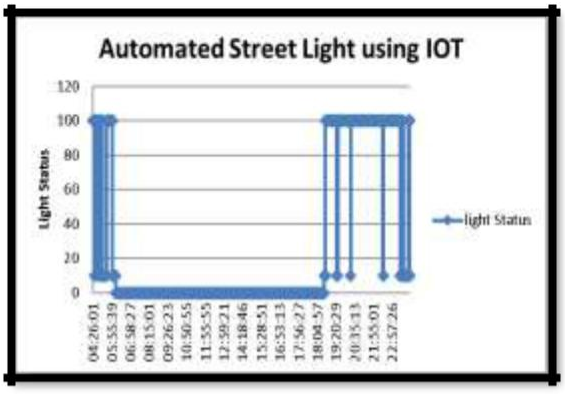
Data generated after implementation of Automatic street light system.

Figure: Sensor Threshold versus Time



The sensor threshold value is at 50 and it has been set for LDR sensor. This depicts that if threshold value is lower than 50 then the light in the street light switches ON. If it is greater than 50, light remains OFF.

Figure: Light Status versus Time

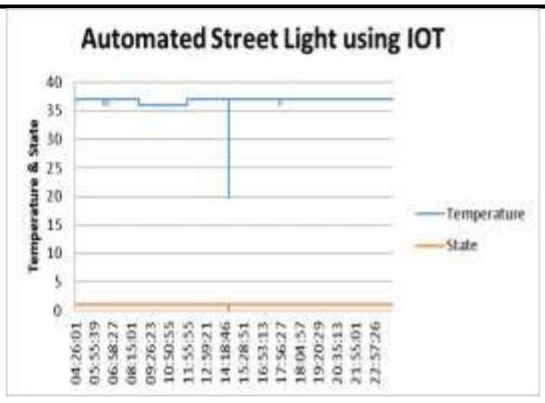


Source: Self – Generated

The graph represents time (Hour: Minutes: Seconds) VS light status (ON/OFF). The light status represents whether the light was in ON or Off mode. As we can see from the graph, that the light status is fluctuating between ON and OFF from 4:26:01 AM till 5:55:39AM, because the light intensity of the atmosphere was low. But from 5:55:39 AM to 18:04:57PM the light status is OFF as it is day time. Again from 18:04:57 PM the light status is flickering between ON and OFF as night is approaching and there is requirement of light. The street light system is ON when the object passes by and is OFF when the object leaves the area around the street light.

The graph depicts a time (Hour: Minutes: Seconds) Vs. Light intensity. From 4:26:01 AM to 6:06:23 AM the light intensity of atmosphere rises and remains constant till 15:59:21 PM. The curve is slowly decreases and then slightly rises (The increase in light intensity can be assumed because of the light intensity of the lights coming from the other sources nearby). The light intensity is higher and remains constant in the day time, so the street light will remain switched OFF. And the light intensity is lesser at night. So the street light will be ON/OFF depending upon the entrance of human being or vehicle.

Figure: Temperature, State versus Time

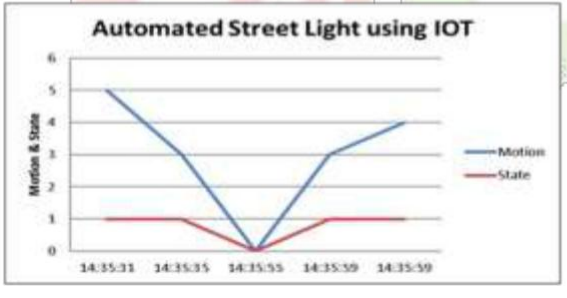


Source: Self – Generated

This data is an input from PIR sensor. State data is sent by the device *to* Cloud IoT Core. State data is returned in binary format. As we see that state remains at 1 throughout the time except at 14:18:46 it becomes 0. It means there has been change to the device.

The temperature curve remains constant throughout the time except at 14:18:46 PM. The temperature has decreased at this point and this shows that there is a possibility of an accident at this point of time as the temperature of the body has reduced or no human being has entered at that point of time.

Figure: Motion &State versus Time



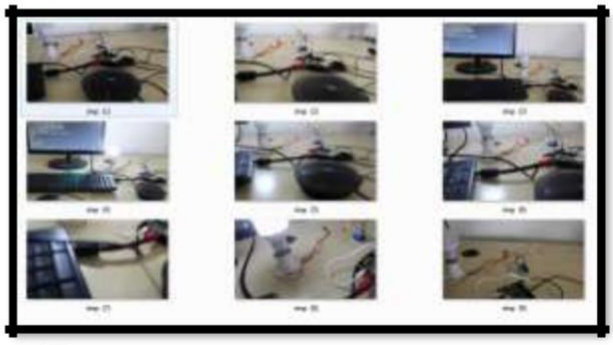
Source: Self – Generated

In this graph the motion and state has reduced and become zero at 14:35:55 PM. This shows that there is no motion at this point or motion has come to rest. The sudden change in the motion gives a possibility of accident or gives another possibility that no human being has entered at this point of time.

Voice Controlled Home Automation System

It is a system which uses Python code to convert speech information into text. This system can switch ON or OFF the bulb, fans, AC, Fridges and other electronic appliances through voice instructions.

Figure: Working of VCHAS

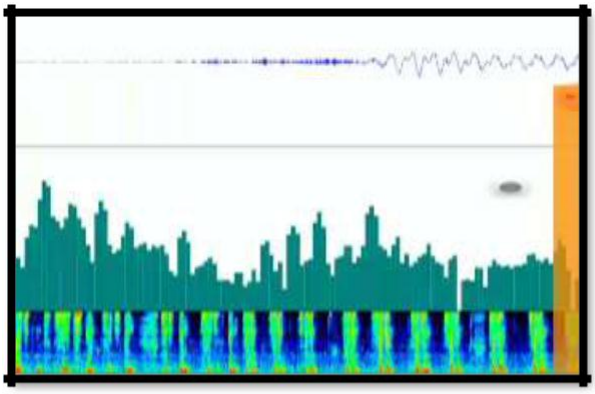


Source: Self – Generated

Data Generated After Implementation of Voice Controlled Home Automation System.

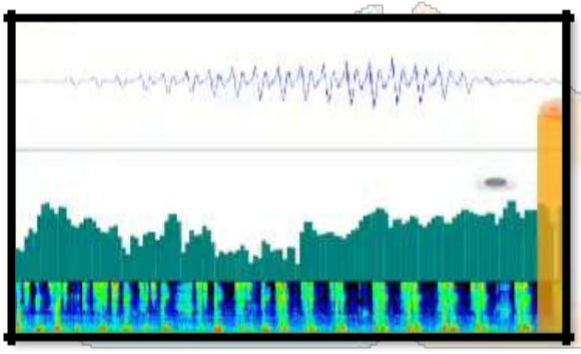
The objective of this section is to recognize the speech of a human, with the help of neural networks. So, in order to reach this objective Switch IN is represented as 0 and Switch off is represented as 1 and this data has to be fed to the system. The 100 voice samples of Switch In and Switch Off have been taken respectively, and the percentage of recognition for different sample sets 10, 20 ,30, 40, 50, 60, 70, 80, 90 and 100 have been calculated for both Switch In and Switch Off.

Figure: 'Switch In' of one Voice Sample



Source: Self – Generated

Figure: 'Switch Off' of one Voice Sample



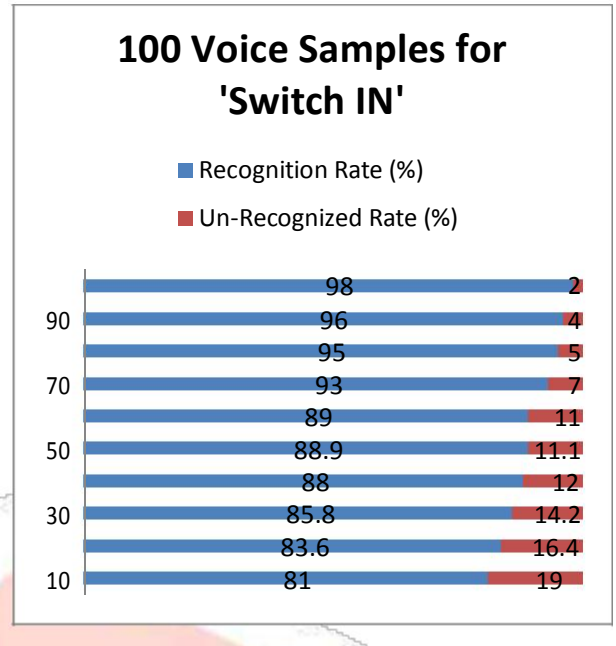
Source: Self – Generated

Table: Recognition rate of 100 Voice Samples for 'Switch ON'.

For 100 Voice Samples	Recognition Rate (%)	Un-Recognized Rate (%)
10	81	19
20	83.6	16.4
30	85.8	14.2
40	88	12
50	88.9	11.1
60	89	11
70	93	7
80	95	5
90	96	4
100	98	2

Source: Self- Generated

Figure: Recognition rate for sample "Switch In".



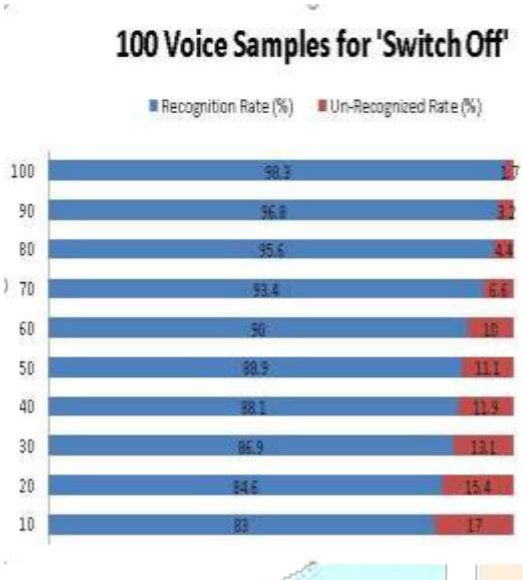
Source: Self- Generated

Table: Recognition rate of 100 voice samples for Switch Off.

For 100 Voice Samples	Recognition Rate (%)	Un-Recognized Rate (%)
10	83	17
20	84.6	15.4
30	86.9	13.1
40	88.1	11.9
50	88.9	11.1
60	90	10
70	93.4	6.6
80	95.6	4.4
90	96.8	3.2
100	98.3	1.7

Source: Self- Generated

Figure: Recognition rate for sample "Switch OFF".



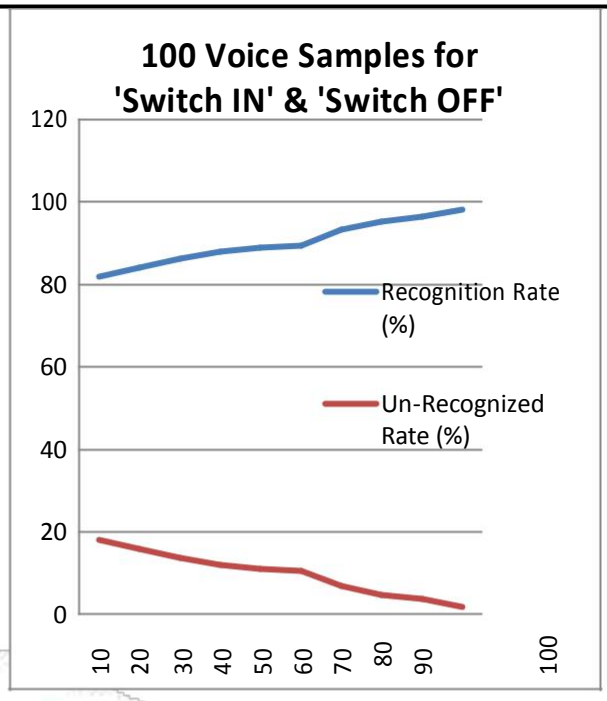
Source: Self- Generated

Calculating Recognition Rate achieved by 100 voice samples

Recognition Rate = Voice (Switch IN (0) + Switch OFF (1)) / 2 X 100%

After calculation of the combined Recognition Rates of both the samples 'Switch IN' and 'Switch OFF', the results have been plotted in the form of a graph given below.

Figure: "Switch In" and "Switch OFF" plotted in graph



Source: Self- Generated

The system uses the voice of about 50 people and gives approximate accuracy of 90.2%. We can conclude that with increase in number of voice sample the recognition rate of the system improves.

(Nilsson) explains that when a machine is given different kinds of inputs which bring change in its structure, then the machine learns and progresses its performance in future. An addition of samples of speech improves the recognition capability of the device, and hence we can say that the machine has learned.

Analyzing and forecasting the moisture in soil using the data provided by the sensors early identification of the possibility of drought in the villages.

i) Understanding the Network Topology of agricultural lands based on moisture content data using Minimum Spanning Tree for early identification of drought in villages.

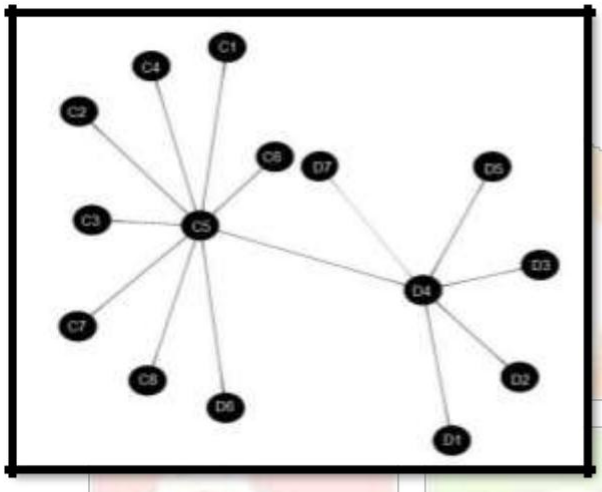
ii) Using the moisture content data of 15 villages generated from the sensors, identifying the optimum forecasting model out of ANN, SVM and AR models, which can forecast the moisture content data with maximum accuracy and minimum error.

ANALYSIS OF MST OBTAINED AT DIFFERENT PHASES

The C series villages are the villages which have NDVI Normalized Difference Vegetation Index and NDWI Normalized Difference Water Index to be normal, which mean these agricultural villages are well in term of irrigation and vegetation whereas in the D series the NDVI and NDWI are mostly severe. These sectors are more prone to drought comparatively.

Stage 1: Vegetative Phase

Figure: Minimum Spanning Tree for Phase 1 (MST 1)



Source: Self- Generated

From the above network it can be seen that C5 is a village with minimum growth rates of moisture content and all the villages of C series which are C1, C2, C3, C4, C6, C7 and C8 have higher growth rate of moisture content than C5. D6 is an exception with higher growth rates. The villages and C3 and C6 have higher correlations with C5 shows that their growth rates are lesser compared to other villages of C series i.e. C1, C4, C2, C7, C8 and D6.

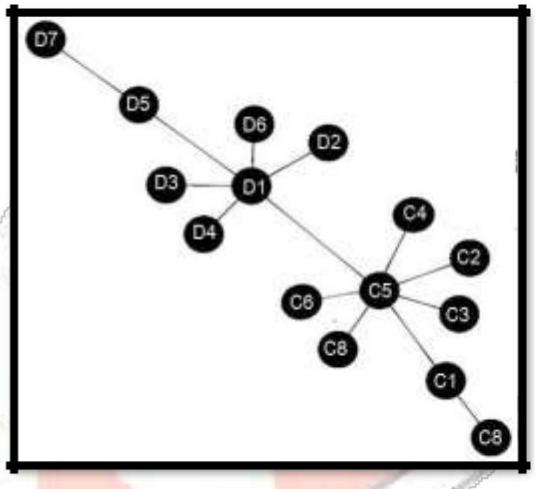
From the above network D4 correlation with C5 shows that, it is a village with maximum growth rate of moisture content in D series and the other villages at the fringe which are D7, D5, D3, D2 and D1 are villages with lesser growth rates of moisture.

The drastic distance between C5 and D4 shows the huge difference in the growth series of C and D series. The minimum growth rate in C series correlates with the maximum growth rate in D series with huge distance.

C5 and D4 are the driving forces of the network. The star structure in the network shows the robustness of the system and its ability to deal with instability is higher.

Stage 2: Reproductive Phase

Figure: Minimum Spanning Tree for Phase 2 (MST 2)



Source: Self- Generated

The duration in this phase is for 30-35 days for every season or variety. This phase is not effected by photoperiod but is vulnerable to lower temperatures, water deficiency &salinity which can lead to sterility.

The amount of water required or used by the soil depends upon the amount of water present inside the soil. If the soil dries it becomes difficult for the plant to take water from the soil. When the field capacity i.e. maximum amount of water present in the soil then plant uses water at a maximum rate but if the moisture content in the soil reduces below the field capacity, then plant can extract lesser water. It can be seen from the network that C5 which was at the center of the network in the previous stage has now moved to the center of the chain like formation of this stage. This could be because the growth rate of moisture water content in the C5 soil has reduced and the extraction of water from the soil has reduced. This can be validated through the association of C5 with villages of D5, D6 and D7.

The other scenario can be that as this stage requires more amount of water, the growth rates of C series are higher than D series. The formation of C series villages around C4 shows that the growth rates of moisture content have improved highly and here the minimum growth rate village is C4 which was at fringe in the previous phase i.e. greater moisture content growth rate than C5.C5 growth rates may have reduced, remained constant or increased respectively. If C5 growth rate has not improved, this shows that D7, D6 and D5 have improved their moisture content growth rates. The shift of the three villages from D4 proves that these villages have improved comparatively.

But if the C5 growth rate has reduced, this shows that D4 being at the fringe of the network had lesser growth rates in its moisture content. As D4 being the village with maximum growth rate in the previous stage. It is the driver of star structure with D1, D2 and D3 shows the vulnerability of the D1, D2 and D3. D3 has higher possibility to be in drought than D1 and D2.C5 has to recover so that it doesn't fall into the possibility of the villages prone to drought. C5 has to recover so that it doesn't fall into the possibility of the villages prone to drought.

The chain like structure of the network shows the uncertainty and vulnerability of villages towards the drought.

Stage 3: Ripening Phase

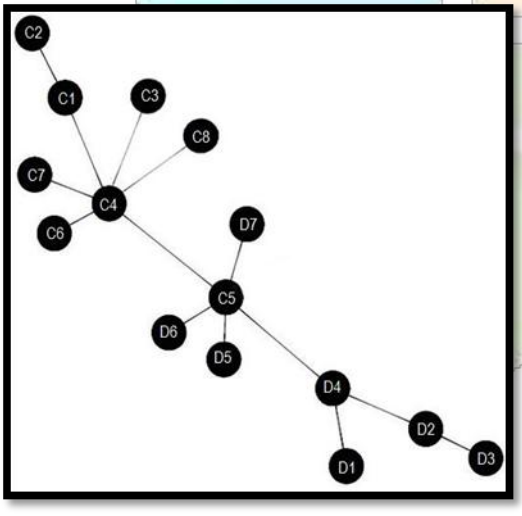


Figure: Minimum Spanning Tree for Phase 3
Source: Self made

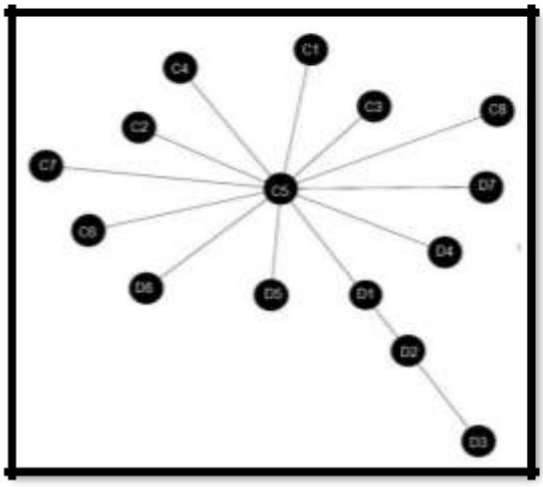
The water requirement in this phase is lesser, as water is drained before the harvest. We can see that C5 has recovered from its previous stages and is

back in the star structure of C series and is the driving force of the network. D1 has moved from the fringe to the core of the network.

The chain like topology shows uncertainty on the anticipations of the drought.

In this stage the graph behaves differently as the water is drained and the samples have been not taken after the occurrence of drought.

Stage4 : Entire Duration
Figure: Minimum Spanning Tree for Phase 4



Source: Self made

Global warming and instability in the irrigation lands made the future of agriculture on stake. So agricultural systems must be adaptable to the extreme changes of yield, economy, nature and social context. Stability, robustness, vulnerability and resilience have been studied throughout the network.

C5 is a village which is the core driver of the network and all the villages are connected to it with a lone exception of D2 and D3 which are the outlier of the network and are connected with D1. The main possibility of these villages lying in the fringe shows these villages are more prone to drought.

This study shows a novel attempt to study drought from many views and integrate it with the growth of the plants, providing guidance for drought mitigation.

Vertex degree is the number of edges or connections a vertex has. The vertex degree shows the connections between the villages at different time phases. C5 is consistently found to be the core of the Agricultural Network. Even though some of the sectors such D7, D6, D5, D3, D4, D1 and D2 have been consistent in their performance, they lie at the peripheral of the networks in almost all the 3 different phases. This could be due to the fact that these sectors may not be related to the other sectors in the agricultural network which makes then to do so.

From the data in the table, it is shown that D1, D2 and D3 are the villages which were under drought. And also from the MST networks the outlier was D3, D2 and D1.

Results of Actual Drought

Table: Results of actual drought

			1st Phase	2nd Phase	3rd Phase
Sector	**Village**	**Variety**	**1St Spell**	**2nd Spell**	**3rd Spell**
D1	**CHINTHADA**	**Paddy**	20-06-18	25-09-18	Drought
D2	**SANTHAGYRAMAPETA**	**Paddy**	21-06-18	26-09-18	Drought
D3	**MUTYAMMAPALEM**	**Paddy**	19-06-18	4/10/2018	Drought
D4	**PEDAMEDAPALLI**	**Groundnut**	22-06-18	31-08-18	31-10-18
D5	**KRISHNAPURAM**	**Groundnut**	23-06-18	12/9/2018	21-11-18
D6	**MANDA**	**Red gram**	6/7/2018	12/9/2018	1/11/2018
D7	**THADIKONDA**	**Red gram**	13-06-18	11/9/2018	3/11/2018

Source: Self compiled (Data of moisture content from 15 villages)

The result shows that MST networks are a suitable technique in predicting the drought prone regions because of it prediction match with actual. The drought formed in the villages D1, D2 and D3 could be identified in the early stage only i.e. Reproductive stage as they were the outliers and in the fringe of the network at that phase. So early identification of drought is helpful in drought mitigation. The drought can be prevented by identifying the village and finding out the source of the cause of drought. Drought could be because of lesser rains throughout the periods, change in temperature between land and water, changes in air circulation, poor rainfall and high temperatures along with excess use of ground water and inconsistent pattern of weather affects the rainfall and leads to drought.

○ COMPARISON OF PERFORMANCE OF ANN, SVM AND AR IN FORECASTING MOISTURE CONTENT

This section is helpful in identifying the model which forecasts the moisture content present in the soils of the respective villages, which will be helpful in determining the village which has more possibility of occurrence of drought. The moisture content is predicted using AR, ANN and SVM models. These models are compared based on the value of MSE and RMSE. Lesser the MSE and RMSE values, higher are the accuracy of the model. The models are trained using the 70% of the data present in the training set. Using the models generated out of training set the testing set is predicted with 30% of the data. The predicted dataset is compared with the actual testing set to find the differences in the results.

▪ Forecasting Using AR Model

The AR models of lag length differing from 1 to 4 have been used.

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Forecasting results of using AR model

AR Model	MSE	RMSE
AR (1)	1.382462919	1.429578047
AR (2)	1.085187989	1.429581661
AR (3)***	1.06603744979554***	1.42958428387095***
AR (4)	1.084903834	1.429570685

Source: Self -compiled

The Autoregressive model of lag 3 AR (3) has least value of MSE and RMSE, so it is considered to be the best model out of the AR models.

Forecasting Using SVM Model

The SVM models of lag length varying from 1 to 4 have been used. The SVM models have been trained based on AR models.

Table: Forecasting results of using SVM model

SVM Model	MSE	RMSE
SVM based on AR (1)	0.143230109	0.378457539
SVM based on AR (2)	0.005720242	0.075632278
SVM based on AR (3)***	0.004893477	0.069953391
SVM based on AR (4)	0.008279469	0.090991586

Source: Self -compiled

The SVM based on AR (3) has least value of MSE and RMSE, so it is considered to be the best model out of the SVM models.

Forecasting Using ANN Model

The ANN models of lag length varying from 1 to 4 have been used. The input nodes are based on the number of lags of AR The hidden layer has 8 layers consisting number of nodes (3, 5, 2, 7, 6, 8, 4, and 1) respectively in each layer and has an output layer of one node.

Table: Forecasting results of using ANN model

ANN Model	MSE	RMSE
ANN based on AR (1)	1.429578046	1.195649634
ANN based on AR (2)	1.429581661	1.195651145
ANN based on AR (3)***	1.42957058513007	1.19564651345206
ANN based on AR (4)	1.429584284	1.195652242

Source: Self -compiled

The ANN model based on AR (3) has least value of MSE and RMSE, so it is considered to be the best model out of the SVM models.

We can conclude that from the above 3 models, SVM based on AR (3) has minimum RMSE and MSE. This SVM models predicts data accurately compared to other models. The SVM models are better than the ANN models which are better than the AR models.

4. Conclusion:

The testing of the prototypes was tested and were in working conditions. The data obtained in the IoT solution were analyzed and dependability of the prototype on the other factors were obtained.

In smart irrigation systems the dependability of the moisture in the soil w.r.t to temperature and humidity has been observed. Whenever humidity is low and temperature is high there is water requirement in soil. And the water is irrigated by the system whenever water deficiency is seen in the soil.

✓ In automatic street light system, the dependability of the lighting on the factors such as light intensity and temperature of the human body has been observed. Whenever the light intensity is low and temperature is more than the surrounding temperature then the smart street light switches ON.

✓ In voice controlled home automation system it has been found that with increase in input of voice samples the recognition rate has improved. (Nilsson) explains that when a machine is given different kinds of inputs which brings change in its structure, then the machine learns and progresses its performance in future. An addition of samples of speech improves the recognition capability of the device, and hence we can say that the

machine has learned.

In objective 2 The moisture data from 15 villages has been used in identification of drought in early stages. MST was used to create different networks among the villages at different stages of plants. ANN, AR and SVM model are used to predict the moisture content data for 4 lags.

✓ It was found that the droughts in the agricultural lands can be identified in the early stages. In actual the drought was observed in the ripening stage but according to the MST networks obtained at different stages, the drought can be identified in the flowering stage because of their behaviour as outliers in the network. When the networks were observed for the entire duration D1, D2 and D3 were the 3 villages which were outliers in the network. In actual also D1, D2 and D3 are the villages subjected to drought. But when the network in reproductive stage is observed, it can be seen that D1,D2 and D3 behave as outliers at this stage only. Hence, the farmer actually identifies drought in ripening stage. But using MST networks will be helpful in early identifications the villages which are likely to be effected by drought .

✓ It was found that out of SVM, AR and ANN models, SVM could predict the moisture content with least error.

SUGGESTIONS

From the objective 1 the IoT solutions are effective solutions to the real time problems in the world. The proper working of IoT prototypes in real time and simulated environment proves their proper working and functioning. The weightage of benefits of IoT solutions are far greater than the conventional solutions. Smart irrigation system, Automatic street lighting system and voice controlled home automation are the solutions for rising problems such as water wastage, increase in electricity consumption etc.

The machine learning techniques like MST can be used for early identification of drought. And proper mitigation steps can be taken to prevent drought. Farmers can save their crops from drought.

Similarly, when it comes to forecasting the time series data, SVM based AR models i.e. hybrid models are better solutions for forecasting among AR and ANN and can be used for better accuracy of forecasting the moisture content.

ANN has better voice recognition ability when compared with AR models. So people can program using ANN to improve the recognition ability of the recognition device.

These solutions such as IoT lighting system are cost effective as they save huge amount of energy.

These lighting systems can be used not only in street lighting but also in corridors or other areas where electricity consumption is higher. If not the systems, then only the sensors can be used to get extract data from devices.

Smart irrigation system is also cost effective as it saves the costs for the farmers and increase their profits. It can also be used for gardening and other planting purposes. If not irrigation system, only sensors can be used to extract data which is useful for other purposes such as forecasting etc.

SCOPE FOR FURTHER RESEARCH

✓ Similarly using machine learning techniques, electric consumption can be forecasted using the data generated by the sensors. And the areas where the highest electric consumption can be discovered and proper steps can be implemented to prevent the electricity wastage.

✓ In forecasting the moisture content, additional data in future can be used to authenticate the models developed and the predicted values can be showcased.

✓ The smart irrigation system can be improved by integrating it with weather monitoring device. If it is forecasted that there is a possibility of rain, then lesser water is irrigated to the plants.

✓ A GSM module can be added to the system through which the irrigation system, street lighting system and voice controlled home automation system can be controlled through

smart phones.

✓ Using IoT for other activities involved in agriculture such as cattle management, fire detection and climate control would reduce the human intervention.

✓ Traffic speed sensors can be used to dim the light in the street lighting system. Dimming would cause the driver of the vehicle to slowdown if the speed of the vehicle is too fast.

✓ Cost effectiveness analysis of voice controlled home automation system can be done.

✓ A proper study on turning the IoT solutions into profitable Indian businesses can be done.

✓ A proper study on marketing the IoT solutions to the Indian end users can be done.

✓ As Blockchain is one of the current cutting edge technology, and its integration with internet of things can improve the limitations of both the technologies. A step ahead than Blockchain and IoT is IOTA (Internet of Things tAngle) can be used in further studies.

✓ A customized business model framework for IoT solutions can be developed by taking a greater sample of interviews from the companies of IoT.

The present research further supports that IoT technology has enormous potential in the fields of irrigation, lighting and home automation. IoT is a cost effective and resource saving solution to day to day problems. And operations can be managed smoothly with the help of this technology. Managers can focus on their core competencies than managing issues. The immense amount of data generated through this solution can be used for analysis. These solutions have potential to be turned into profit making business with the help of a synergy fit business model.

And also in order to address the security issue of IoT with respect to its data. National Institute of Science and Technology (NIST) is focusing on making a lightweight encryption algorithm as standard. NIST has received about 56 LEA in round 1 and has chosen 32 out of them in the next round. It has held 2 conferences in 3 years on LEA. By 2021, NIST is expected to make a standard LEA as a solution to problem of security in IoT devices. So high focus has to be given to security in IoT devices.

The applications of IoT range from HR, banking, marketing to Finance and many more. It is essential for HR to appreciate the consequence of people analytics that comes from IoT. By means of IoT solutions, financial institutions get actual data on their assets and customers. Understanding a customer's behaviour, buying patterns, and place also provides a level of attribution, analytics, and predictive abilities that were not present at first are present in the field of marketing. IoT is also helpful in efficient management of supply chain and inventory management. India predicts about 5 billion IoT connections by 2022, and an economy of $1 trillion by 2025.This shows that sooner or later IoT will become a reality from a concept, and hence is necessary for both the businesses and consumers to adopt IoT.

REFERENCES

Accenture. (2014). *The internet of things:Adoption of consumer*. Accenture.

(n.d.).

Aggarwal, R., & Das, M. L. (2012). RFID Security in the Context of "Internet of Things". *First International Conference on security of internet of things,Kerala*, 51-56.

Kokilavani, M., & Malathi, A. (2017). Smart Street Lighting System using IoT. *International Journal of Advanced Research in Applied Science and Technology*, 1-2.

MacGillivray, C., & Torchia, M. (2018, september). *Worldwide Internet of Things Forecast, 2018–2022*. Retrieved from IDC.

Vermesan, O., Bahr, R., & Gluhak, A. (2016). IoT Business model framework. *H2020 – UNIFY-IoT Project*, 7-8.

Agrawal, S., & Vieira, D. (2013). "A survey on. *Abakós, Belo Horizont*, 78-95.

Biddlecombe, E. (2009). "Internet of things". *UN predicts*.

Bullough, D. J., & Rea, M. S. (2009). *ANALYSIS OF VISUAL PERFORMANCE BENEFITS FROM ROADWAY LIGHTING*. Troy: Lighting Research Center, Rensselaer Polytechnic Institu.

Chona, A. (2017, July). *What is the next stage of Iot means for supply chain management*. Retrieved from CXO insights.

COE-IoT. (n.d.). Retrieved from COE-Iot website: http://www.coe-iot.com/

Darshana, S., Sangavi, T., & Mohan, S. (2015). Smart Irrigation System. *IOSR Journal of Electronics and Communication Engineering (IOSR-JECE)*, 1.

Eini, R., Linkous, L., & Zohrabi, N. (2019). A Testbed for a Smart Building: Design and. *ResearchGate*, 1.

empxtrack. (n.d.). *How Internet Of Things (IoT) Will Impact HR?* Retrieved from empxtrack: https://empxtrack.com/blog/how-internet-of-things-will-impact-human-resources/

Fujii, Y., Yoshiura, N., & Takita, A. (2013). Smart street light system with energy saving function. *Conferance paper*.

Futureiot editors. (2019, April 22). *2019 use cases of IoT in financial*. Retrieved from Futureiot: https://futureiot.tech/2019-use-cases-of-iot-in-financial-services/

Gainey, J. (2018, july). *Hubspot*. Retrieved from 6 Predictions for the convergence of IoT and digital marketing: https://blog.hubspot.com/marketing/6-predictions-for-the-convergence-of-iot-and-digital-marketing

Group, A. T. (n.d.). *How IoT is Impacting the Financial Services*. Retrieved from Acadia technology group: https://www.acadiatech.com/blog/how-iot-is-impacting-the-financial-services-industry/

Hussam, M., & Presser, M. (2018). Comparison of seven Business Model innovation tools for Iot Ecosystems. *IEEE 4th World Forum on Internet of things*, 68-73.

Ju, J., Kim, M. S., & Ahn, J. H. (2016). Prototyping Business Models for IoT Service. *Information Technology and Quantitative Management*, 886.

Kamdar, N., Sharma, V., & Nayak, S. (2016). A Survey paper on RFID Technology, its Applications and Classification of Security/Privacy Attacks and Solutions. *IRACST - International journal of computer science and Information Technology &Security*.

Kosmatos, E. A., Tselikas, N. D., & Boucouvalas, A. C. (2011). Integrating RFIDs and Smart Objects into a UnifiedInternet of Things Architecture. *Advances in Internet of Things: Scientific Research*, 5-12.

KPMG. (2018). *The changing Landscape of disruptive technologies*. KPMG.

Kumar, G. R., Gopal, T. V., & Sridhar, V. (2018). SMART IRRIGATION SYSTEM. *SMART IRRIGATION SYSTEM*, 1.

Liu, P., Wang, J., Sangaiah, A. K., Xie, Y., & Yin, X. (2019). Analysis and Prediction of Water Quality Using LSTM Deep neural Networks in IoT Environment. *MDPI*.

Madakam,, S., Ramaswamy, R., & Tripathi, S. (2015). Internet of Things (IoT): A Literature. *Journal of Computer and Communications*, 164-173.

Ministry of Communications. (n.d.). *National Digital Communications Policy 2018.* Retrieved from department of communication Website: http://dot.gov.in/sites/default/files/EnglishPolicy-NDCP.pdf

MyIndia. (2015, february 26). *Street Lighting in India and Need for Energy-efficient Solutions*. Retrieved from MyIndia: https://www.mapsofindia.com/my-india/government/street-lighting-in-india-and-need-for-energy-efficient-solutions

Nilsson, J. N. (n.d.). *INTRODUCTION.* Stanford.

Ogidan, O. K., Onile, A. E., & Adegboro, O. G. (2019). Smart Irrigation System: A Water Management Procedure. *Scientific Research Publishing*, 1.

Pan, J., Jain, R., & Paul;, S. (2015). An Internet of Things Framework for Smart Energy in Buildings: Designs, Prototype, and Experiments. *ResearchGate*, 1.

Rajesh, A., Antony, A., Jose, F., & Kumar, R. S. (2018). IoT Based Smart Street Light System. *Asian Journal of Applied Science and Technology*, 1.

Ramli, N. L., & Yamin, N. M. (2015). IMPLEMENTATION OF PASSIVE INFRARED SENSOR IN STREET. *ARPN Journal of Engineering and Applied Sciences*.

Roy, K. D., & Ansari, H. M. (2014). Smart Irrigation Control System. *International Journal of Environmental Research and Development.*, 1.

Shiklo, B. (n.d.). *ScienceSoft*. Retrieved from IoT-driven inventory management: https://www.scnsoft.com/blog/iot-for-inventory-management

Soujanya, C. S. (2018). *Automatic Street Light System Using Lora Wireless Communication.*

Sullivan, J. M., & Flannagan, M. J. (1999). *ASSESSING THE POTENTIAL BENEFITOF ADAPTIVE HEADLIGHTING USINGCRASH DATABASES.* U.S.A: University of Michigan Transportation Research Institute.

Torchia, M., & Shirer, M. (2019, January). *IDC Forecasts Worldwide Spending on the Internet of Things to Reach $745 Billion in 2019, Led by the Manufacturing, Consumer, Transportation, and Utilities Sectors*. Retrieved from IDC: https://www.idc.com/getdoc.jsp?containerId=prUS44596319

TRAI's M2M recommendations: Licenses, Privacy, Entry Fee, Spectrum sharing & more. (n.d.). Retrieved from MEDIANAMA: https://www.medianama.com/2017/09/223-trais-m2m-recommendations/

Wnuk, K., & Murari, B. t. (2016). The impact of internet of things on software business models. *Researchgate*, 1.

Writer, G. (2017, September 28). *4 Ways IoT Changes the*. Retrieved from iot for all: https://www.iotforall.com/4-changes-iot-in-financial-services-industry/

Zantalis, F., Koulouras, G., Karabetsos, S., & Kandris, D. (2019). A review of machine Learning and IoT in smart transporatation. *future internet*.

Zantalis, F., Koulouras, G., Karabetsos, S., & Kandris, D. (2019). A Review of Machine Learning And Iot in smart transportation. *future internet*.

Zhao, Q., Xia, L., & Jiang, Z. (2018). Project report: new generation intelligent building platform techniques. *Energy Informatics*, 1.