SMART IRRIGATION MANAGEMENT SYSTEM
USING LORA WAN BASED SENSOR NODES

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Abstract

One of the main factors which contribute to the food crisis is the population growth. Also increased urbanization reduced the land area for cultivation. So the importance of obtaining high yield from the available cultivable area has gained attention nowadays. Good yield from the crops can be obtained only if proper irrigation is provided. From the early days itself, farmers have found it as a difficult task since the water requirement for each crop is different. Also the timing to irrigate the land is important because of climatic changes in the different seasons. It is in this scenario that smart irrigation becomes important. Automation is a trendy topic in the 21st century, making it an important part of our daily lives. The main attraction of any automated system is to reduce human labour, effort, time and error. This work presents an automatic irrigation system which makes use of machine learning technology to decide the time and duration of the irrigation. Soil Moisture, Soil Temperature, Atmospheric Humidity, temperature and Pressure are sensed from different points of the field and are transmitted to the controller using LoRa wireless technology without making use of LoRa gateway. These data are used for predicting the soil moisture for the upcoming hours, which is used to decide the duration for irrigation. Random Forest Classifier is used for the prediction of soil moisture. LoRa provides long range, low data rates with low battery consumption.

1. Introduction

The capacity of a country to feed itself adequately depends on the handiness of arable land, available water and the pressures of the population. There's enough food produced around the world to feed us, but this food doesn't always reach the poor, and thus the infrastructure to support it. The world population is estimated to increase by about 2.3 billion people by 2050, according to the United Nations Food and Agriculture Organization (FAO). And population and economic growth will cause worldwide food demand to double. This rapid rise and consequently the associated difficulties would put greater pressure on food production. Food production relies on cropland and water supply processes that are under stress as human populations grow. Agricultural production can have a determinant of the quality of the soil. Research suggests that about one percent of the Earth's soil supports farming. Owing to unsustainable agricultural practices, a 30% of this cultivable soil is projected to erode awareness by 2050.

Earth is referred to as "the water planet." The proper picture of a world with ample water comes with that name. But less than 3 percent of Earth's water is freshwater. Most of that 3 percent is not accessible. Around 68% of the freshwater on Earth is found in ice caps and glaciers and just over 30% in groundwater. Only 0.3% of freshwater is found in the surface water of lakes, rivers, and swamps. Agriculture withdraws about 70% of global water withdrawals.

Irrigation is the process by which external means such as drains, ditches, sprinklers etc. are often used to supply a controlled volume of water. Owing to drainage, evaporation and over-watering inefficiencies, modern watering methods will waste as much as 50 per cent of the water. Smart irrigation systems use sensors to say watering routines for real-time or historical data, and to adjust watering schedules to improve performance. Agriculture is often badly affected because of erratic, inadequate or unpredictable rainfall. Proper irrigation systems will safeguard continuous farming. Irrigated soil quality is higher than ground with unsuitable irrigation. In irrigated countries, crop yields are significantly higher elsewhere within the developed world than in rain-fed regions. The germination of seeds requires moisture, so that seeds cannot expand in dry soil. With the help of irrigation supply, the required moisture content of soil for the growth of seed can be properly ensured.

Through irrigation, it is possible to supply the required amount of hydrogen & oxygen to the crops, which is important for the proper development of plant roots. A plant can absorb mineral nutrients from the irrigated soil. Thus, irrigation is important for the overall growth of the plant. The key objectives of irrigation systems are to help grow agricultural crops, protect the soil, reduce the effects of inadequate rainfall etc. The value of irrigation systems is therefore extremely high. Due to inefficiencies in irrigation, evaporation and over-watering, conventional watering methods may waste as much as half the water used.

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Fig. 1 Smart Irrigation using sprinklers

Smart irrigation systems use sensors for real-time or historical data to inform watering routines and modify watering schedules to enhance efficiency. Smart irrigation systems offer a lot of advantages over traditional irrigation systems. Smart irrigation systems can optimize water levels based on soil parameters and weather predictions.

2.   Proposed System

The proposed system is a smart irrigation system which makes use of sensor nodes for the purpose of sensing the field parameters. The sensor data is transmitted to the data processing system using LoRa Technology. Here the soil moisture is predicted and accordingly decision for irrigation is made. This is then transmitted back to the sensor node to which the motor is connected. The required input parameters for the data processing system are obtained from the sensor node. The sensors used are, soil moisture sensor, soil temperature sensor, atmospheric pressure sensor, relative humidity and air temperature sensor. Also, the solenoid valve for turning on and off the sprinkler is connected to this node.

LoRa Technology can perform very-long range transmission with low power consumption. LoRa technology can be used to transmit bi-directional information to long distances. LoRa relies on chirp spread spectrum modulation, which maintains an equivalent low power characteristic as FSK modulation but significantly increases the communication range. LoRa uses license-free radio frequencies such as 169 MHz, 433 MHz, 868 MHz (Europe), and 915 MHz (North America).

The sensor nodes mainly employ four sensor types. Pressure sensor, soil temperature sensor, soil humidity sensor, air temperature, and humidity sensor. Today barometric pressure sensors contribute to weather forecasting requirements. Barometric pressure sensors monitor variations in the atmospheric pressure. The impacts of soil temperatures include: photosynthesis, transpiration, demand for water in the soil, soil trans-location and microbial activity [Valente2006]. Measurement of the soil temperature is needed because of this. The volumetric quantity of soil vapor is determined by the soil humidity sensors. Air temperature and humidity sensor measures, monitors, and records the temperature of humidity and air.

Machine learning is an artificial intelligence (AI) technology that provides systems the ability to learn and develop automatically from experience without any explicit programming. Machine learning is designed to create computer programs that can view and use the data to learn about themselves. This system uses Random Forest Classifier for the purpose of prediction. Random forest classifier generates a set of decision trees from a randomly selected training set sub-set. This then aggregates the votes from various decision trees for the final class of the test item to be determined.

Irrigation is planned according to the water holding capacity of the soil. Soil moisture is expressed as volumetric water content (%). The water in the soil is deposited both on the surface of the soil particles and in the pores, which are gaps or openings between individual soil particles. Pores must contain both water and air or oxygen. The amount of soil moisture depends on temperature, runoff or drainage, and soil quality.

3. Literature Survey

Yu-Chuan Chang et.al [Chang2019] provides a smart irrigation system based on machine learning with LoRa P2P networks. The device can measure the amount of water for each irrigation and then automatically irrigate the crops through the wireless LoRa P2P long distance and low power network. The center of this system is the gateway to LoRa which makes the system costly to implement.

Goapp, Amarendra, et.al [Amarendra2018] presents a technology-based open-source smart device to predict field irrigation requirements by sensing ground parameters such as soil moisture, soil temperature, and environmental conditions, along with web weather forecast info. ZigBee technology is used to collect sensor node data wirelessly using internet network infrastructure, and a cloud-based knowledge analysis and decision support framework offers real-time insights into information based on sensor data interpretation and weather forecast data.

In their paper Goldstein, Anat, et al. [Goldstein2018] aims to use the data collected not only to track and manage the crop but also to forecast recommendations for irrigation. Different regression and classification algorithms were applied on this data set to construct models which could predict the weekly irrigation built by the expert as advised.

Shekhar, Yuthika, et.al [Shekhar2017] developed an Intelligent IoT-based Automated Irrigation system which captured soil moisture and temperature sensor data. This is completely machine controlled wherever devices communicate and apply the knowledge of irrigation to one another. It was created to victimize embedded devices such as Arduino Uno, Raspberry Pi3, that are low price. The Intelligent IoT-based Automated Irrigation System is developed using M2M, a part of IoT that allows devices to communicate with other devices where moisture and temperature sensors are deployed in the field of agriculture to capture field watering information.

Ravi Kishore Kodali et.al [Kodali2018] laid out a smart irrigation network based on the LoRa system. The system controls the various atmospheric variables such as temperature, humidity, and crop water volume, using sensors such as temperature, soil moisture, and water flow. The module is connected via the internet to IBM cloud using the WiFi stack module in LoRa which displays the continuous qualities. It helps to track irrigation pumps and sprinklers from remote locations by the farmer or IBM Bluemix.

4. Lora Technology

LoRa is the physical layer or wireless modulation used to render the communication connection for the long range. LoRa is based on the modulation of the chirp spread spectrum, which retains the same low power characteristics as the modulation of FSK, which is used by other wireless communication systems but greatly improves the range of communication. Owing to the long transmission distances and robustness to interference, chirp spread spectrum has been used for decades in military and space transmission. LoRa is the first low cost application of the chirp spread spectrum for commercial use.

LoRa's benefit lies within the long-range potential of the system. Scope strongly depends on the climate at a given position or obstructions. Nevertheless, LoRa has a link budget greater than any other structured communication technology. The link budget is the primary think about determining the range in a given environment. With a minimum amount of infrastructure, it can effectively cover whole countries.
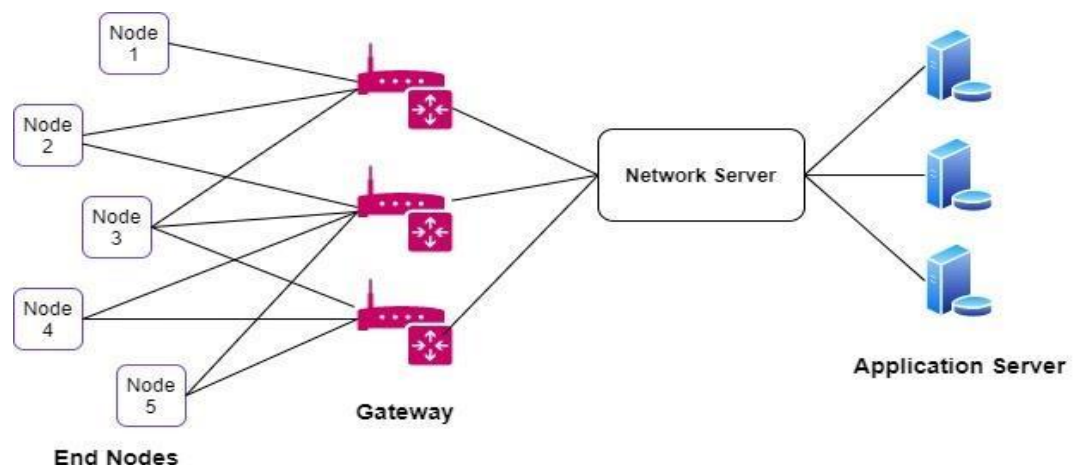

Fig 2 LoRa Network Architecture

LoRaWAN specifies the communication protocol and system architecture for the network, while LoRa's physical layer allows the long-range communication link. The protocol and network design have the primary influence in deciding a node's battery life, network efficiency, service quality, health, and hence the variety of network-serving applications. LoRa features include IoT Software, Home and Build Automation, Long Range Communication, Industrial Monitoring and Control etc.
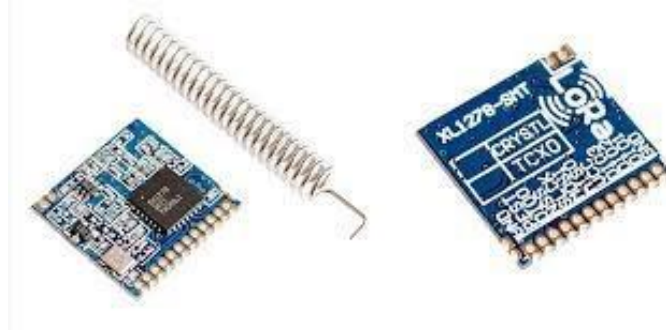

Fig. 3 SX1278

The XL1278-SMT module is a low cost RF front-end transceiver module that is based on Semtech Corporation's SX1278. It retains the advantages of RFIC SX1278, but simplifies the design of the circuit and is suitable for applications with limited range and low data rate. For the mini SX1278 LoRa, the 5-Km wireless transceiver module consists of one RFIC SX1278, a thin SMD crystal and a corresponding antenna circuit. The port of the antenna is well suited to a standard 50-part impedance and a 433 MHz spring coil antenna. The LoRa SX1278 works with an SPI communication protocol so it can be used with any SPI compatible micro-controller. It is mandatory to use an Ariel (antenna) along with the module otherwise it may permanently damage the module. The module should only have 3.3V power supply.

5.   Methodology

The complete system can be divided into 3 main sections. In the Sensor System, the required parameters for the purpose of real time prediction are collected. Each node consists of different sensors that are connected to a micro-controller. Also the solenoid valve for operating the pumping of water is connected to this sensor node. In the Wireless communication system, the values that are collected are transmitted over wireless channels to the main data processing system and the feedback from the data processing system is transmitted back to the sensor node. In this system LoRa wireless technology is used for this transmission. Data Processing system is the main section of the system. The data transmitted from the sensor nodes are subjected to machine learning algorithms for the prediction and according to this prediction, the irrigation is planned. This will be a computer system.
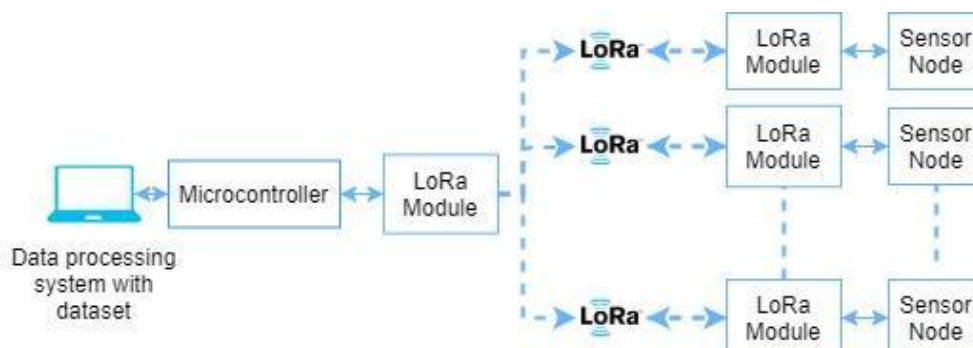

Fig. 4 Overall System

The detected values from the sensors are passed to the microcontroller. The micro controller is connected to the LoRa module via an SPI interface and these sensor values are passed to the data processing system

through LoRa technology. After the data is processed, the decision for operating the solenoid valve is received through the LoRa module and accordingly the irrigation is done.
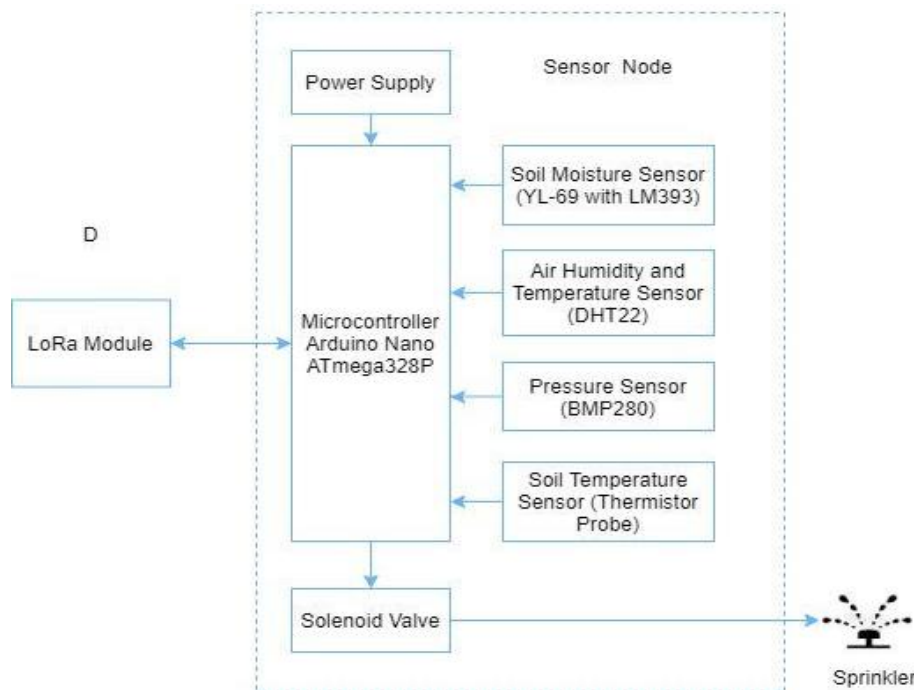

Fig. 5 Sensor Node

The different types of sensors used are:

1. Pressure Sensor (BMP 280)
The BMP280 is a barometric pressure sensor that is feasible for mobile applications. It is possible to incorporate battery-powered devices such as cell phones, GPS systems or watches due to its small size and low power consumption. The BMP280 is based on the piezo-resistive pressure sensor technology with high precision and linearity. The device is configured regarding power consumption, resolution and efficiency of the filter. This has an operating range from 300 to 1100 hPa, and a temperature range from -40 to 85 degree Celsius. It operates at power supply of 3.3V. It can produce performance in the 300 to 1100 hPa range. Average measuring time of 5.5msec is needed.

2. Soil Temperature Sensor
The soil temperature sensor is a 10k NTC thermistor probe. It works on the principle that the resistance changes according to the change in temperature. The Steinhart and Hart equation is used to determine the corresponding temperature. The Steinhart and Hart Equation is an empirical formula defined to be the most powerful mathematical formula for the relationship of NTC thermistors and NTC probe assemblies with resistance temperature.

3. Soil Moisture Sensor (YL-69 with LM393)
The soil moisture sensor or the hygrometer is usually used to detect the humidity of the soil. The sensor for soil moisture consists of two probes which measure the volume of soil water. The two probes allow the electrical current to pass through the soil and, depending on its resistance, measure the soil moisture level. The soil conducts more energy when there is more water, ensuring the resistance will be less. Thus the level of moisture will be higher. Dry soil reduces conductivity. So the soil absorbs less energy when there is less water, which means it has more resistance. Thus the level of moisture will be lower. It operates on 5V power supply.

4. Air Temperature and Humidity Sensor (DHT22)
The DHT22 is a simple, low cost digital temperature and humidity sensor. To measure the surrounding air, it uses a capacitive humidity sensor and a thermistor and spits a digital signal on the data pin. Using it is fairly easy, but it requires careful timing to capture data. New data is collected from the sensor once every 2 seconds, which is the real downside of this sensor. This sensor is more sensitive, more reliable and operates in a broader temperature / humidity spectrum, but it is larger and more expensive. It operates on 5V power supply. It can provide an output from 20% to 80% for humidity and a temperature range of -40 to 80°C.

The data are transmitted by different sensor nodes at different time intervals so that the receiver LoRa module could identify each node and process them separately.

6.   Results and Discussions

Dataset is prepared by making use of Thingspeak cloud. The data from the sensors are transmitted to the cloud by making use of WiFi. The data are collected at intervals of 30 minutes. Plot of the variation of water content in the soil under natural conditions is as in the following figure.
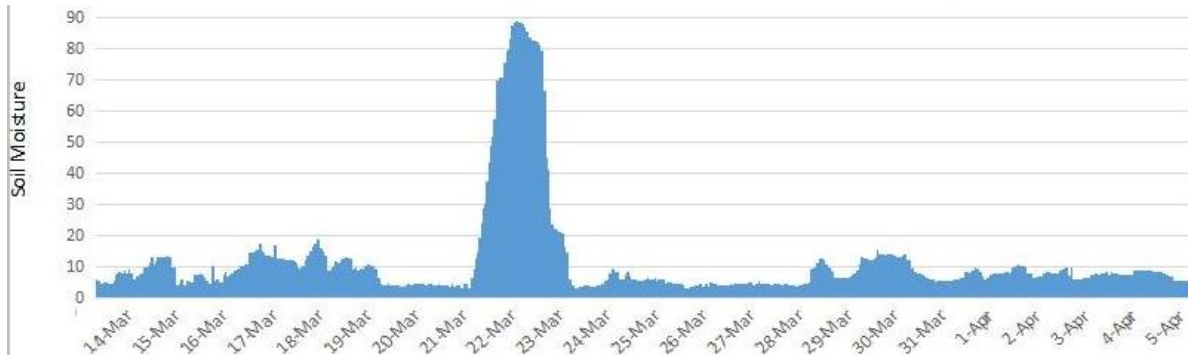

Fig 6. Plot showing the variation in soil moisture under natural conditions

Multiple sensor nodes are placed at different regions of the agricultural field, which senses the different field parameters and these are transmitted to the data processing system via LoRa module at different time intervals such that the data from other nodes do not overlap. After processing the data, the duration for irrigation is decided and is transmitted to the sensor node to which the sprinkler is attached.
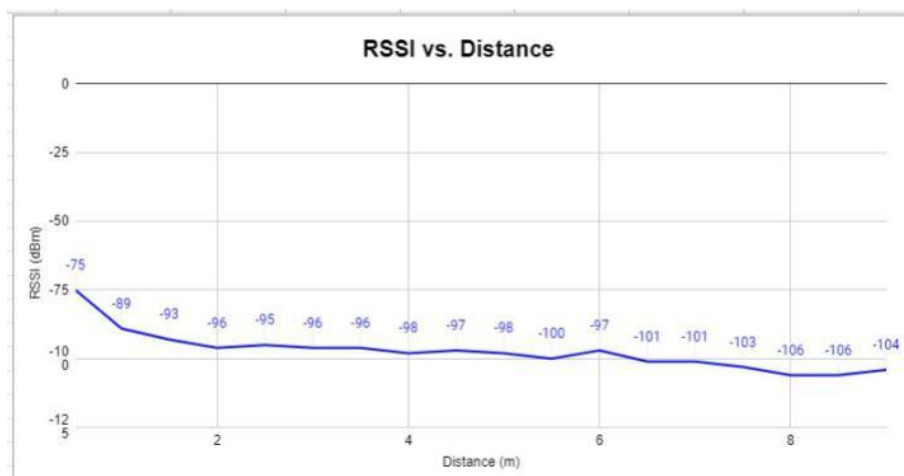

Fig 7. Sensor Node Implementation

Fig 8 RSSI V/s Distance graph

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The RSSI V/s Distance graph is plotted. RSSI, or "Received Signal Strength Indicator," is a measurement of how well the device can hear a signal from an access point. It's a value that is useful for determining whether there is enough signal to get a good wireless connection. It shows that, as the distance increases, the strength of the received signal is decreased.

A suitable algorithm to make the prediction is chosen according to the accuracy of a particular method for the given dataset. For these 8 methods were tested for its accuracy with the dataset. Random Forest Classifier is found to be the one with highest accuracy. This is used to predict the soil moisture.

Fig 9. Table showing the predicted and observed soil moisture

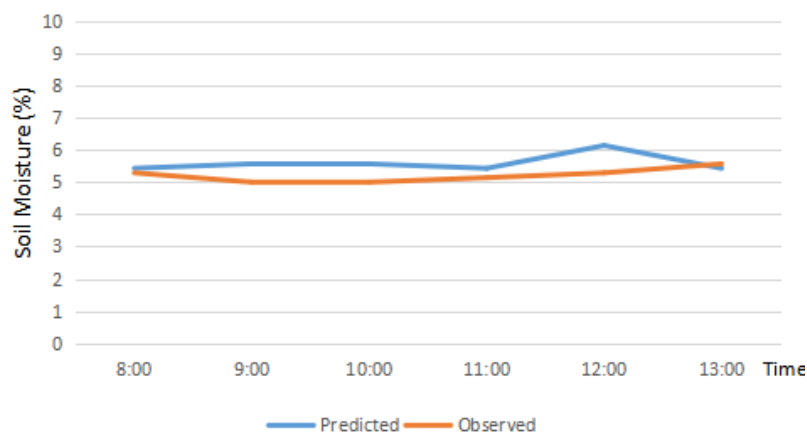| Time	Predicted soil moisture (%)	Obtained soil moisture (%)
8:00	5.43	5.29
9:00	5.57	5.00
10:00	5.57	5.00
11:00	5.43	5.14
12:00	6.14	5.29
13:00	5.43	5.57

Fig 10. Plot of predicted and observed soil moisture

7.   Conclusion

Smart irrigation systems are used in-order to reduce the wastage of water and to increase the yield. The proposed system is useful in cases where there is large areas for cultivation and the human intervention is difficult. The intelligent system predicts the upcoming soil moisture values and accordingly the irrigation is planned. Novel LoRa technology is used for the purpose of sensing parameters from long distances for large farming ares can be made available such that appropriate irrigation can be done. The received data is used to predict the soil moisture for the coming 6 hours. Since the most accurate algorithm is used, chance for occurrence of error is minimized. The comparison with the real time sensed values are done such that the error factor can be calculated. Random Forest Classifier is found to be the most accurate one, which is used for the purpose of prediction. From the predicted values the duration for the irrigation is decided and this is transmitted back to the sensing node to which the solenoid valve is attached. Also the mean squared error is estimated using the predicted and the observed values. The mean squared error is found to be 0.249.

8.   Future Scope

The global, national and regional networks will need to serve billions, or even trillions of devices in the future. LoRa will play a significant role in providing future applications with a smart, low cost, and highly efficient network. Automated technologies are not only performing iterative tasks in the coming days but also significantly increasing the capacity of the workforce. In fact, the expectation is that automated systems will replace almost half of the global workforce. In agriculture, automation has a very important role to play which requires a lot of manpower and time. The system can be implemented in the different regions surrounding a

building or organization with different atmospheric conditions such as availability of sunlight, different rate of evaporation, varying availability of water, etc. It can also be applied for those crops that have crucial water requirements.

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