Proceedings of the International Conference on Intelligent Computing and Communication for Smart World (I2C2SW-2018)
14-15 December 2018

Smart Irrigation System using Zigbee Technology and Machine Learning Techniques

R.N. Kirtana
Department of CSE
SSN College of Engineering
Chennai, India

B. Bharathi
Department of CSE
SSN College of Engineering
Chennai, India

S. Keerthana Priya
Department of CSE
SSN College of Engineering
Chennai, India

S. Kavitha
Department of CSE
SSN College of Engineering
Chennai, India

B. Keerthana
Department of CSE
SSN College of Engineering
Chennai, India

K. Kripa
Department of CSE
SSN College of Engineering
Chennai, India

***Abstract*—Agriculture plays a massive role in India's economy with nearly 60% of its land still under cultivation. In such scenario, managing the scarce water is a critical issue in this era. Therefore, a smart irrigation mechanism is necessary to improve the crop productivity. Smart irrigation can be achieved by combining the potential of Internet of Things (IoT) with machine learning algorithm(s), which supports automation and fast forward enhancements in the agricultural field. In this paper, design and implementation of a Smart Irrigation System (SIS) that automates the irrigation process in an ideal and accurate manner using machine learning techniques (decision making) is detailed. In the first module (sensor), various parameters such as the moisture content of soil, temperature and humidity of air are obtained from the field and transmitted to a local base station through Zigbee technology (IEEE 802.15.4).Second module is the base station, where Raspberry pi is used for computation and learning. That is, a classification model is built using the training set and predicts the crop water requirement (ETcrop) for the new parameters. In addition, the sensor module is solar powered, thus reducing power consumption and enhancing the system's robustness.**

Keywords—Smart Irrigation System, Internet of things, Machine learning, Classification, Zigbee, Raspberry pi

I. INTRODUCTION

India, being a developing country with increasing population is mostly dependent on Agriculture and it accounts for a considerable share in the country's Gross Domestic Product (GDP). Traditional Irrigation system of India includes groundwater systems, rainwater harvesting projects and various canals that can serve fields with water from rivers. With the erratic monsoon and decreasing ground water level due to global warming, it is high time to adopt smart irrigation.

With life being more associated with devices in this era, the rise of Internet of Things (IoT) technology plays an appreciable role by connecting embedded systems to internet and those devices exhibit themselves digitally[1]. Such devices could be monitored and controlled from anywhere at any time. With the utilization of IoT technology becoming a necessity for its ubiquitous and scalable nature, it proves to be highly suitable for improvements in the agricultural arena. On the other hand, Machine Learning (ML) is an interesting field and which can help in solving real time problems.ML models are extensively used for automation where human intervention is reduced as well as improving performance over a period of time. Adapting new data independently is one new feature found in Machine learning. It can be applied to take the decision on various constraints. That is, in the Agriculture, given piece of land many ways should be found to increase productivity ,as the urban sprawl occurs at the cost of land which is suitable for ploughing.

There are quite a few related works in this domain, where the efforts have always been taken up to bring a automation process in irrigation systems. However, many important aspects are not considered in making necessary decisions based on the current condition of the land, which will be discussed later in the literature survey section. Even the work(s) which have tried utilizing the benefits of ML algorithms are not cost effective and sustainable solutions. Hence, a Smart Irrigation System (SIS) is proposed in this research work, to overcome the shortcomings in the existing systems and as well as any other current method of irrigating the farms that aims at improved crop productivity while managing the water resources ideally.

In the proposed system, there are two primary modules. One is the sensor module that measures various parameters such as the soil moisture, air temperature and humidity using appropriate sensors. This sensor module is to be placed on the farm and transmits the data through Zigbee technology to the base station. Zigbee technology has been proved useful in home networks like health monitoring systems [2]. There could also be multiple sensor nodes on the field and to transmit data. The second module is the base station, which uses Raspberry pi (RPi) as its computing platform over which a prediction model is built and tested for new parameter using ML algorithm. I f the decision is to irrigate, the RPi will take actions to control the motor through Radio Frequency technology. By doing so, adequate and right amount of water is provided to the farm. This will enhance the productivity of the crops as well as avoid under irrigation and over irrigation. The paper is split into following sections: Section II details about literature survey.

Section III explains the design of proposed smart irrigation system. Implementation and results are illustrated in Section IV. Conclusion is given in Section V along with future scope.

II. RELATED WORK

In [3], growth characteristics of turmeric and disease in turmeric finger are closely observed with the help of sensor based system. The Electrical signals from the temperature, pH, flux sensors which are placed on the field to monitor the growth characteristics of turmeric are converted to digital values and it is processed and stored in microcontroller and transmitted via ZigBee to central node and uses GSM technology for storage in remote location. Here microcontroller can store data for three days which reduces power consumption.

In [4], the raw data from the DHT22, YL100 sensors which measures the air temperature, humidity and the soil moisture respectively are fed into WeMos board which sends them to the Azure IoT Hub which monitors every IoT devices and links them periodically. Using Stream Analytics, millions of records per second are stored in database. It uses machine learning and compares the actual values obtained from sensors with the threshold value that has been fed to the machine learning for analysis. After this process, the machine learning cross checks the results obtained with the weather forecast and the decides whether to be irrigated or not. The farmer will receive the notification on smart phone and he can choose to turn on the water pump with button click. It also has the webapp which further helps the farmers to analyze the statistics throughout the time period.

In [5], the system uses Arduino board which controls the digital connections and acts as the bridge between the sensors and the mobile phone application. It optimises the irrigation while addressing the issue of water shortage by inducing judicial use of water through innovative IOT based technique. The smart irrigation module can be modified according to the specific need of different crops. This data can be stored on the server. Based on the crop selected by the farmer on the mobile application, data would be retrieved from the server and the system would adjust itself accordingly, resulting in efficient irrigation and increased harvest.

In [6], a preliminary design was proposed for paddy cropping, Banana and Turmeric fields in our nearby localities on the real-deployment of WSN .Data loggers are used for acquiring data from different sensors. The architecture of the system focused on low power consumption catered the most important and critical issue nowadays in WSN monitoring. The new design architecture of the system is explained from the sensor node hardware to the management system which can be easily installed and maintained. The scope for future work in this study will include fabrication, experimental investigation, data analysis, control solution and complex networks setups.

In [7], the idea is to maintain the soil moisture content and temperature in a farming area and the user can control Sprinkler using Android phone/tab. This paper is based on Android and Raspberry pi platform both of which are Open Source Software. So, the overall implementation cost is cheap. The design consists of Android App by which user can interact with the android phone and sends control signal to the Raspberry pi to control sensors and also raspberry pi monitors the environment. Thus user can control their farm from remote location by using Android mobile.

Remote monitoring of moisture content of soil, temperature of soil and humidity of air for Agriculture is implemented using Zigbee in [8]. For monitoring agricultural parameters,it serves as a reliable and efficient system. The corrective action can be taken. Wireless monitoring of field allows user to reduce the human power, and also allows user to see accurate changes in it. It is cheaper in cost and power consumption is less. The GDP per capita in agro sector can be increased. This project can be extended for cattle monitoring.

The sensors used in the various papers of smart irrigation system are described below:

VH200 sensor [9] monitors the soil water content at low cost providing precise measurement and it is small in size ,insensitive to salinity ,probe does not corrode over time, consumes less than 7mA power and it is not conductivity based Probes come in standard cable lengths of 2 meters, 5 meters and 10 meters.

The THERM200 sensor [10] helps in observing the soil temperature and can withstand temperature range from -40°C to 85°C.Calculating temperature from voltage is easy here and there is no need for complex equations becausethe output voltage of this sensor is linearly proportional to temperature.. This sensor consists of three wire interface which includes power, ground and output. It is supplied with power ranging from 3.6V to 20VDC, and output voltage will be between 0V to 3V,where 0Vdenotes -40°C and 3V denotes 85°.Ii is also a low cost sensor which consumes power less than 3mA and can be buried and is water proof.

DHT11 [11] is ahigh cost performance Humidity and Temperature Sensor, which generates calibrated digital output with high reliability and long term stability. It has a humidity sensing component, a NTC temperature sensor (or thermistor) and an IC on the back side of the sensor. DHT11 can be interface with any microcontroller like Arduino, Raspberry Pi, etc. and get instantaneous results. DHT11 Humidity Sensor consists of 4 pins: VCC, Data Out, Not Connected (NC) and GND. The range of voltage for VCC pin is 3.5V to 5.5V. A 5V supply would do fine. The data from the Data Out pin is a serial digital data.

III.PROPOSED SMART IRRIGATION SYSTEM

The proposed system is aimed to bring about precision in irrigation systems by automating the process with the help of machine learning technique. There are two modules in this system namely Sensor module and Base station module. In Sensor module the corresponding humidity and temperature ensors are placed. The data is then transmitted to the second module which is a base station. Base station analyses the data obtained and automates the process of irrigation. The working and need of each component is described in detail below.

A. Sensor Module (on farm)

In this module, the required sensors are placed on the farm that acquires land's condition (depicted as (A) of Fig. 1 and (B) of Fig. 1).

1) Sensor nodes (wireless)

The sensor node(s) that are wirelessly interconnected consist of various sensors such as the soil moisture (VH400), soil temperature (THM200), air temperature and humidity sensor (DHT11). These sensors placed appropriately on the land are finally wired to the xbee s2 transceiver. The xbee component makes use of the zigbee protocol to transmit data to the base station [8]. The sensors to be used are reliable and provide results with acceptable precision.

2) Zigbee Protocol

A standard for wireless communication between wireless devices that has been recently established is Zigbee. The greatest advantage is that it is both open and standardized globally. With popularity of Zigbee, devices incorporating the usage have overtaken other short-range wireless technology.It is eaily merged into systems across the IoT industry via gateways of Zigbee. The Zigbee protocol is secure and stable, which is one of the reasons why it has become one of the world's most widely adopted protocols.

The usage of Zigbee protocol (picturized as (B) of Fig. 1) has been widely used and preferred for short range communication in wireless networks. Setting up Zigbee network is very simple and easyover other technologies. As Zigbee protocol is secure and stable. There are many devices that could possibly use this zigbee protocol, yet XBee is a microcontroller with 20-pin framework which is highly efficient and low-powered.

The xbee at land((B) of Fig. 1) will be the router and is responsible for the sensors on land by being connected to them. This will be set to AT mode. The XBee at base station will be connected to the Raspberry pi platform ((A) in Fig.1). This XBee will act as the central one for the network and is setto work in the API manner to obtain data from the sensor modules of the router on land. XBees The network is scalable and it is easy to add/remove Zigbee end devices to the network. Zigbee eliminates single point failure.There could be multiple sensor nodes that form a mesh topology on which the Zigbee technology is based upon. Through this, the sensor nodes can transmit data to its destination by passing on to different intermediate nodes. This acts as a big advantage over Bluetooth technology.

B. Base Station

1) Raspberry Pi

Raspberry pi devices are miniature computers of credit card sizes. They offer a similar computing environment as that of the computer in a smaller dimension (shown as 2.(A) in Fig. 1). It has 1GB storage capacity that enables medium programs to reside on them and 512MB RAM capability supports the device's usage to perform computations in a smaller environment quickly. Additionally, these have 40 GPIO pins that act as general purpose input/output pins to connect various compatible sensors/electronic devices. Therefore, this is highly suitable to perform computations related to data processing.

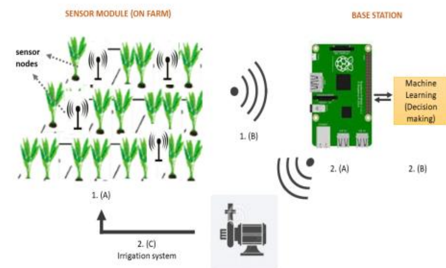

Fig .1. Design of proposed system

2) Machine learning techniques

The proposed system is much oriented towards supervised machine learning techniques where the data that is provided to the model is labelled, i.e, the end target class is known beforehand.The proposed system focuses on smart irrigation system as a classification problem. The data generation phase acquires the data from farm, of which 70% of the data is used for training the classifier and remaining is for testing. Multiple classifiers such as ID3 (Iterative Dichotomiser 3), CART (Classification and Regression Trees), SVM (Support Vector Machine) are used in parallel to decide which model behaves well for the soil and crop constraints.Fig.2,shows the database schema to be utilised as training and test dataset for the machine learning algorithm.

Timestamp	Air Humidity	Air Temperature	Soil Moisture	Soil Humidity	Prediction Class

Fig.2. Parameters of dataset

Based on the four major parameters namely Air humidity, Air temperature, Soil moisture and Soil humidity, the best splitting criterion using ID3 algorithm would be found and generate the decision tree for the data set which have been collected from the field using the sensors. Prediction classes contain two different categories, to_irrigate and not_irrigate. Timestamp for every entry to dataset is noted for representation of historical data.With the help of decision tree, it will be able to decide whether to irrigate or not.The pseudo code for ID3Decision Tree is as below[13].

DecisionTree(Samples,Final_Attribute,Attributes)

Construct a decision tree with Root node

If all the samples are greater than or equal to 0,

Then Return Roottree labelled as To_irrigate.

If all the samples are less than 0,

Then Return Root tree labelledasNot_irrigate

If predicting attributes countisnull,

Then Return Root tree labelled with Final_Attribute's most common value in the samples.

Else

Begin

S ← Attribute that best splitssamples.

Assign S as the Decision tree attribute for root.

For each value,$v_i$of S,

Attach a new branch below Root, corresponding to the test S = v_i.

Let Samples(v_i) be the subset of samples that

have the value v_i forS

If Samples(v_i) is null,

Then Add a leaf node below the newbranch labelledas most common finalvalue in the samples

Else

Add the subtree DecisionTree(Samples(v_i),

Final_Attribute, Attributes – {S}) below the new branch

End

Return Root

The model that behaves well has to be offered to the farmer for predictive services. Depending upon the decision taken by the machine learning algorithm, the control to operate the irrigation system (as shown 2.(C) in Fig.1) through radio frequency technology. Thus, adequate and an ideal amount of water is provided to the crop depending upon its level of growth cycle.

IV. Implementation And Results

On an addition to RPi as the computing platform, Arduino Uno is used as the ARM microcontroller to transmit the sensor data to the RPi platform on a timely basis. The Fig.3, shows the setup of testing the sensor node.

The system is tested with Indian native soil. Data from the sensors is being collected and stored.The stored data will be fed as input to the machine learning algorithm for further analysis. The connectivity detail of Arduino to other components is given in Fig.4

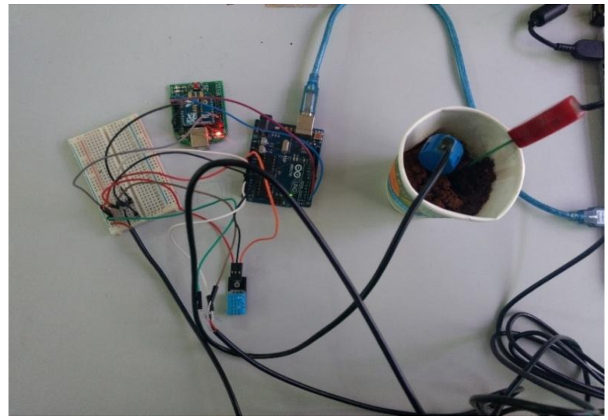

Fig.3. Sensor node setup for testing

ARDUINO TO OTHER COMPONENTS

- Pin A0 → Soil Temperature (THM200)
- Pin A2 → Soil Moisture (VH400)
- Pin RX → Router Xbee TX
- Pin TX → Router Xbee RX
- GND → GND (VH400, THM200, DHT11, XBEE)
- 3.3 V → DHT11
- 5V → VCC (VH400, THM200, XBEE)
- Arduino act as the intermediate microcontroller to transfer the data collected to the Coordinator Zigbee.

Fig.4. Connectivity detail of Arduino to other components

COM3 (Arduino/Genuino Uno)

```
----------------------------------------------
air temp = 33
Humidity == 58
soil moisture == 47
soiltemp === 201
~□□□ÿþt33h58m47s201d--------------------------------------------
air temp = 33
Humidity == 58
soil moisture == 47
soiltemp === 201
~□□□ÿþt33h58m47s201d--------------------------------------------
air temp = 33
Humidity == 58
soil moisture == 47
soiltemp === 201
~□□□ÿþt33h58m47s201d--------------------------------------------
air temp = 33
Humidity == 57
soil moisture == 47
soiltemp === 201
~□□□ÿþt33h57m47s201e--------------------------------------------
air temp = 33
Humidity == 57
soil moisture == 47
soiltemp === 201
~□□□ÿþt33h57m47s201e--------------------------------------------
air temp = 33
Humidity == 58
soil moisture == 47
soiltemp === 200
~□□□ÿþt33h58m47s200e
```

Fig.5. Data received from sensors visualised in Arduino terminal

The snapshot shown in Fig. 5 (Arduino terminal) shows the data collected from the various sensors.

The Fig. 6 shows the transmission of data collected from sensors through one xbee to other xbee.It is visualized through the XCTU software. XCTU is an application designed in view to make interactions with Radio frequency modules through a simple and easy-to-use graphical interface such as xbee here in our system. XCTU provides tools to configure and test xbee, hence is suitable for use in our system to test the reception of the sensor data at the xbee that acts as the coordinator.

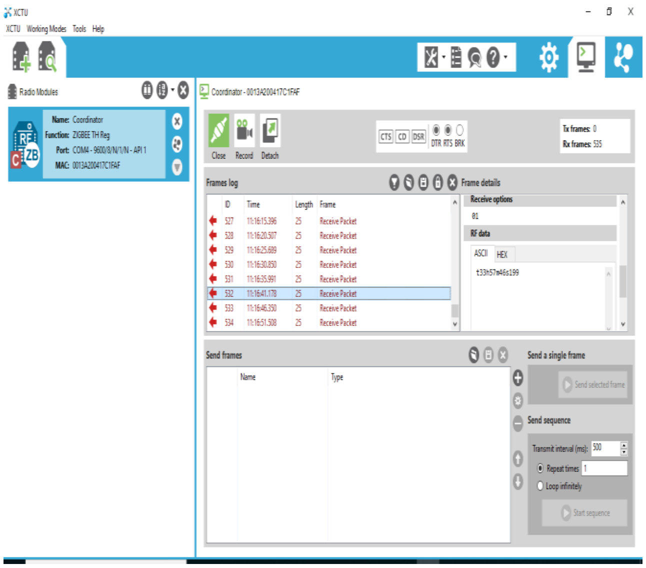

Fig.6. Data received at the Xbee coordinator side

As the above implementation is for testing of the sensor module, the utilisation of the acquired dataset is yet to be implemented in the base station that has Raspberry pi as the computing platform. The second module which is the base station part with machine learning part has to find the suitable ML technique.

V. CONCLUSION

A Smart Irrigation System has been proposed to overcome the water scarcity and it establishes a more efficient way of irrigating large area of crops with minimal, to hopefully zero, wastage of water. There are two different modules namely the sensor module and the base station module. With respect to implementation part of the proposed system, the sensor module is deployed in the farm with VH400 (soil moisture), THM200 (soil temperature sensor) and DHT11 (air humidity and temperature). VH400 and THM200 are the reliable calibrated products for measuring soil temperature and soil moisture level. Hence it is used in our system to provide enhanced accuracy of measured values. The sensors are optimistically placed on the farm and will transmit the data through Zigbee technology to the base station. As discussed in the implementation section, the sensor module is tested in a local environment and the data are collected via an intermediate microcontroller combined with xbee. The heart of base station module which is yet to undergo implementation is the Raspberry pi (RPi) platform. It is easier to install a Linux based operating system on the miniature RPi and hence, Python programming that supports data analytics package could be used to deploy the machine learning model. Rpi is not just a computing platform kind, but also supports various digital and analog components to connect, communicate directly through its general purpose input/output pins. Thus, any sensor/digital component like the xbee could be plugged in to receive the data at the RPi end. This proves RPi as a highly suitable component of the proposed system.

A novel approach of using machine learning is undertaken in this Smart Irrigation System unlike the prevailing existing models in practise. The proposed ML model has the ability to make decision in a better way than humans. In addition, the productivity of crop is increased with minimum water usage. This field of smart irrigation systems are not used widely in reality due to power consumption issues and the durability of the system. However, the proposed system, attempted to overcome these issues with a solar powered sensor node, thus reducing the power consumption. Even in case of a failure node in the sensor module, using the Zigbee technology that follows mesh topology propagates the results through other active nodes in the farm.Thus, the proposed system here is a highly cost effective and idea smart irrigation system in all ways.

REFERENCES

[1] Kirtana, R.N. and Lokeswari, Y.V., An IoT based remote HRV monitoringsystem for hypertensive patients. In 2017 International Conference in Computer, Communication and Signal Processing (ICCSP) pp. 1-6, 2017.

[2] Shanmugam, M., Ramasamy, A., Paramasivam, S. and Prabhakaran, P., .Monitoring the turmeric finger disease and growth characteristics using sensor based embedded system—a novel method. Circuits and Systems, 7(8), pp.1280, 2016.

[3] Kissoon, D., Deerpaul, H. and Mungur, A., A smart irrigation and monitoring system. International Journal of Computer Applications, 163(8), 2017.

[4] Sukriti , Sanyam Gupta , Indumathy K., IoT based smart irrigation and tank monitoring system.International Journal of Innovative Research in Computer and Communication Engineering, 4(9), September 2016

[5] Ravi, D.K.S., Tapaswi, K., Lokesh, B., Krishna, G.S. and Ravi, K.S., Smart sensor system for agricultural chronology. K. Srinivasa Ravi et al/(IJCSIT) International Journal of Computer Science and Information Technologies, 2(6), 2011, pp.2650-2658.

[6] Gauri tope, A.S. Patel., Smart Irrigation System. International Journal of Current Engineering and Scientific Research (IJCESR), ISSN (PRINT): 2393-8374, (Online): 2394-0697, 3(3), 2016

[7] Chavan, C.H. and Karande, M.P., Wireless monitoring of soil moisture, temperature & humidity using Zigbee in agriculture. Int. J. Eng. Trends Technol, 11, 2014, pp.493-497

[8] Wireless Mesh Networking RF Module - Digi International.[Online]. http://www.farnell.com/datasheets/27606.pdf. [Accessed: Feb- 2018].

[9] http://www.vegetronix.com/Products/VH400/

[10] https://www.vegetronix.com/Products/THERM200/

[11] https://www.electronicshub.org/dht11-humidity-sensor-arduino/

[12] https://www.tutorialspoint.com/data_mining/dm_dti.htm

[13] https://en.wikipedia.org/wiki/ID3_algorithm

[14] https://machinaresearch.com/news/agricultural-iot-will-see-a-very-rapid-growth-over-the-next-10-year