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Smart agriculture using IoT

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ABSTRACT

IOT based smart agriculture is a breakthrough in the agriculture sector that gives better solution for water conservation, reduces labour cost, electricity conservation and helps the farmer to keep a record of his yields throughout the year on a wireless mode. This research paper deals with an IoT based application for sustained farm practice by sensing the soil moisture from the soil using the soil moisture sensor module, communicating over internet by the ESP-8266 Wi-Fi module that controls the switching of the submersible motor pump (motor driver-289D) via Arduino Uno R3. The communication request is created by the computer on the given web page of THINKSPEAK APP from the server which further displays the real time sensor values and the pump status in a graphical form. The prototype was designed and tested to sense the real time soil moisture values, send it to the Arduino via the serial communication over the ESP-8266 Wi-Fi module that further plots this value on the created THINGSPEAK channel and is made user-friendly via using virtuino app in the mobile, which enables the remote monitoring the soil moisture values and thus assisting the control of the water pump.

1. Introduction

IoT allows to connect with things, for example we could use our smart phones to obtain information on the packet of food in a super market (E-Food Analytics) or monitor the heart rates (E-Health), manage transportation (Autonomous smart cars), smart home, smart farming etc. IoT finds wide range of scope in the field of home automation, health sector, agriculture sector, transportation etc. Using IoT we are giving the world a digital nervous system similar to our own brain, enabling data collection using sensors on par with our sensory organs using the microphones and cameras connected to internet. The IoT can offer a range of capabilities from monitoring the weather to sensing our vital stats and making them available anywhere around the world. It is projected that 50 billion devices would be connected over internet by 2020. Due to which there will be a huge demand in IoT developers. Irrigation is the process of watering the crops the required amount of water for their natural growth and reaping process. Unfortunately, the existing ways of irrigating the crops are not that effective when it comes to water conservation, energy management, remote accessing, labour requirements etc. Therefore, opting IoT based irrigation is the future of agriculture all over the world (Table 1). The world in witnessing a rapid rise in decreasing water tables, drying up of water bodies like rivers and tanks, fragile environment present an urgent need for judicious utilization of water. Irrigation for agriculture being the major consumer of ground water, it is essential to implement intelligent irrigation systems using temperature and moisture sensor at suitable locations for monitoring of crops is implemented in. [1] An algorithm scripted with threshold values of temperature and soil moisture can be fed into a microcontroller-based gateway to manage pumping of water into the farm area. The system can be powered with IOT based communication link that allows data monitoring and irrigation scheduling to be programmed through a web page. [2] The technological development in Wireless Sensor Networks has paved way for its use in monitoring and control of greenhouse parameters in precision farming. [3] Over a period of time, in several small and marginal landholding there is a decrease in yield as well as shortage of manpower to carry out farm activities. Some of the research attempts are done for betterment of farmers which provides the systems that use technologies helpful for there is a dire need to deploy technological systems for increasing the farm yield.

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Table 1
Challenges in IoT.

Challenges Type	Description
Security and data governance	Companies are concerned that they would connect their physical data environment the cloud which comes with the threat to the data security.
Data and analytics complexity	Huge amount of data collected from the sensors possess a problem of storage, accessibility, usability
Lack of data protocol standards	Having a consistent protocol for all of the data collected is big problem
Diversity of niche providers and solutions	To find the best value of product from the diverse availabilities
Confusion on where to get value (ROI)	Profit validation
Technical infrastructure	Due to availability of wide range of IoT solutions for various sectors, there is still confusion in setting up the generalized technical infrastructure.

Table 2
Comparison of conventional and automated method.

Conventional Method	Automated Method
Manually operated	Autonomous with zero manual intervention
Irrigation scheme is based on real time weather and soil conditions observed manually	Pre-programmed irrigation scheme and not based on real time data
Watering schedule based on farmer's experience	Historical weather and soil data are used as input parameters
Highly dependent on manual labour and their availability	Usually time triggered
No remote access or monitoring access	No remote access or monitoring access

A remote sensing and control irrigation system using distributed wireless sensor network which can aid variable rate of irrigation by deploying real time field sensing, control of a location specific precision linear move irrigation system to maximize the productivity with minimal use of water has been identified by researchers [4]. Such systems were using field sensor stations to collect the data and transmit to the base station using global positioning system (GPS) based on which steps for controlling irrigation were initiated. Such systems provide a reliable low cost wireless solution as well as remote controlling for precision irrigation. [4].In the studies related to wireless sensor network, researchers measured soil related parameters such as temperature and humidity. Sensors were placed under the soil which shared data with relay nodes by the use of effective communication protocol providing very low duty cycle thereby increasing the life of soil monitoring system. Such a system was designed using microcontrollers, universal asynchronous receiver transmitter (UART) interface and sensors while the data sharing was done on time spaced sampling, followed by buffering, transmission and finally checking the status messages. The drawbacks of such systems were their cost and deployment of sensor under the soil which caused attenuation of radio frequency (RF) signals [5]. With the advent of IOT based technologies, allowing connectivity across devices breaking the geographical barriers has to be explored for building smart irrigation systems which shall both be efficient and cost-effective for the small and marginal farmers. This study has been pursued in this direction with the objective given in Table 2.

2. Operational aspects of the hardware

The YL-69 soil moisture probe is inserted close to the root nodes of the sample plant. This probe is connected to the YL-38 soil moisture sensor module that is used to sense the soil moisture content and send the real time data over a wireless medium range Wi-Fi module.
The Wi-Fi module used over here is esp8266 (esp-01 type) which further sense the soil moisture data to the cloud server, which stores the data and displays for the convenience of the user in graphical forms.
This display is obtained on the webpage of Thinkspeak app.
This sensed value is also sent to the Arduino UNO R3 and according to the program depending upon the required moisture content, a command is sent to the L293D motor driver that controls the switching on and off of the submersible DC water pump.
Depending upon the sensor values, the motor is turned on and the water is supplied to the sample plant until the soil moisture probe commands the Arduino to turn it off (when it is more than threshold level).
Wi-Fi module now receives the new sensor data and the new value is updated over the Thinkspeak channel created.

The ESP8266 which is embedded with 32– bit microcontroller, having a working power range of 3.0–3.6 V, with a system on chip with capabilities for 2.4 GHz Wi-Fi, built-in TCP/IP Stack, SPI & UART communication enabled, has been used which shall be able to work as a standalone unit (Table 4). The advantages of using

Table 3
Parametrical description.

Parameter	Description
Objective	To control the switching of the motor pump based on the real time soil moisture data that can be viewed by the user.
Social Problem Addressed	Scarcity of water, food demand, need for remote accessing technology due to changing lifestyle
Technical Problem Addressed	Lack of IoT developers in the agriculture sector, need for remote accessing of the real time data for ling run profits and ROI
Central Concept	Internet of Things, Arduino controlled switching of pump based on wireless serial communication over ESP-8266 Wi-Fi module
Solution	Demonstration of smart agriculture using IoT prototype while assuming the field to be of one acre.
Outcome	Water conservation, energy conservation, reduced manual labour cost, remote access to monitor the data , user friendly project

Table 4
Specification data's.

Parameters	Values
Voltage	5 V
Current	< 20 Ma
Interface type	Analogue
Working temperature	10 °C- 30 °C

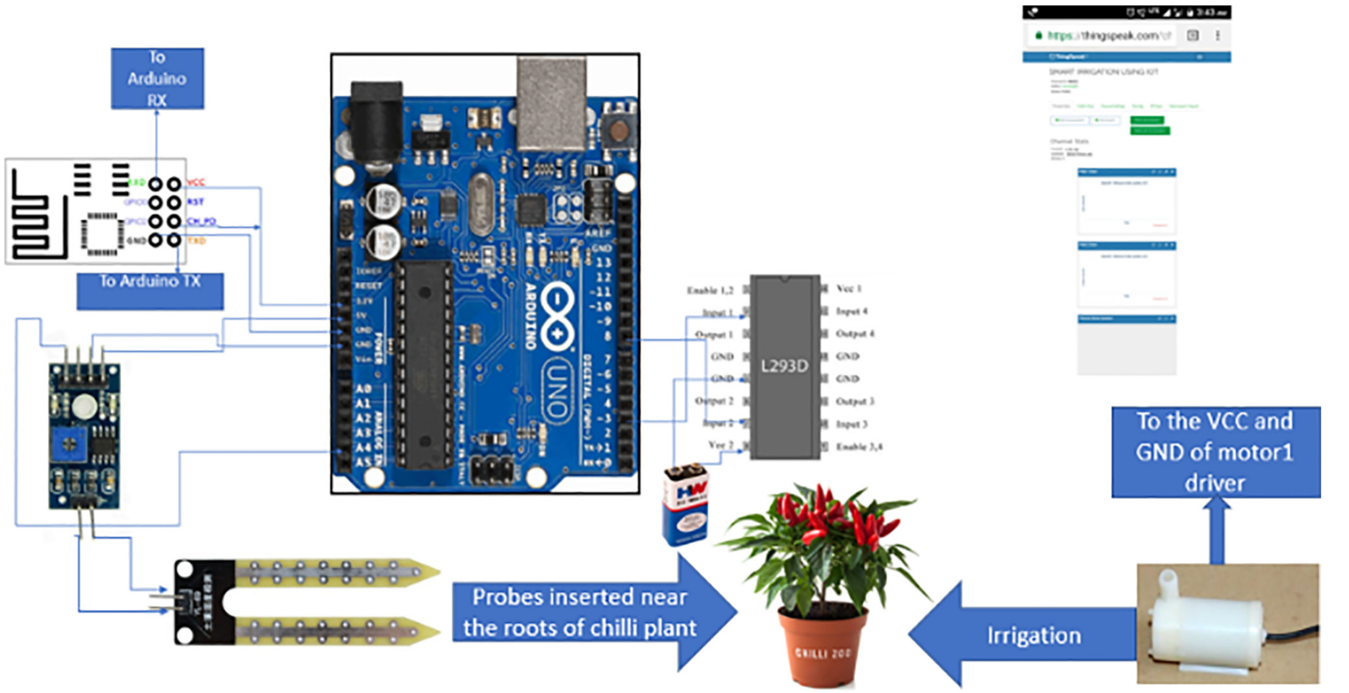

Fig. 1. Hardware Layout.

ESP8266 being the leading platform for internet of things, low cost, dual functionality, self- contained to host entire application, has Wi-Fi adapter to other microcontrollers. While Arduino will serve as the microcontroller and ESP8266 shall act as the Wi-Fi adapter for the IOT communication. It has multiple GPIOs pins to interface with sensor in advanced version (Table 3). The hardware layout is shown in Fig. 1.

2.1. Pin configuration

The VCC and GND pin provide power to the board. RESET pin is an input pin for external reset signal. It works in active low mode. CH-PD is for enabling the chip, the chip works properly when it is high. Tx and Rx pin are used for transmission and reception for serial communication. It has two GPIO pins which can take digital input or provide digital output. The Pin configuration is shown in Fig. 2.

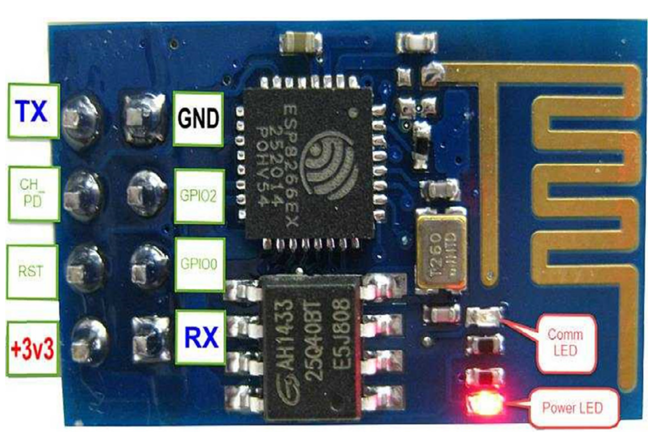

Fig. 2. Pin Configuration.

Fig. 3. Soil moisture sensor.

2.2. Soil moisture sensor

The soil moisture sensor is used to measure the amount of water content in the soil surrounding it. It is a low tech. sensor which is ideal for monitoring an urban garden, so it is perfect to build an automated watering system or to monitor the moisture content of your plant using this sensor. The sensor is setup by two pieces: the electronic board and the probe with two pads that detects the water content as shown in Fig. 3. This sensor uses two probes to pass current through the soil, and then reads that resis-

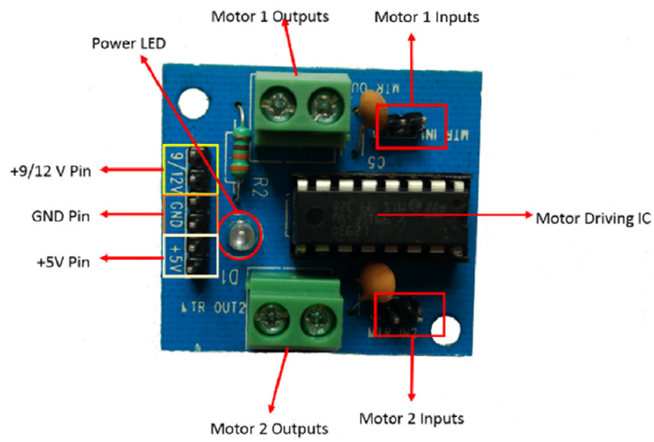

Fig. 4. L293D – Pin image.

tance to get the moisture level. The sensor has a built-in potentiometer for sensitivity adjustment of the digital output.

The sensor measures volumetric water content in the soil. This measurement id done indirectly by using some other properties like

1. Electrical resistivity
2. Dielectric resistance
3. Interaction with neutrons

YL-69 sensor has been used in this study as shown in Fig. 4. It works based on the principle of electrical resistivity of the soil by measuring how strongly the soil resists the flow of electricity between the electrodes can be used to determine the soil moisture content. The output of the soil moisture sensor module can be digital signal D0 (high or low) depending upon the water content. Threshold value for digital signal can be adjusted using the potentiometer. When there is shortage of water, the module output becomes high (the output voltage of the sensor increases). When there is more water content, the module output becomes low (the output voltage of the sensor decreases). The soil moisture sensor module was connected to the Arduino. The change in the sensor data was observed depending upon the change in the moisture level of the soil.

2.3. Submersible water pump

A submersible water pump is a device which has a hermetically sealed motor close coupled to the pump body. The whole assembly is submerged in the fluid to be pumped. The main advantage of this type of pump is that it prevents pump cavitation's problem associated with high elevation difference between pump and the fluid surface. Small DC submersible water pumps push fluid to the surface as opposed to jet pump having to pull fluids. Submersibles are more efficient than jet pumps. It is usually operated between 3 V and 12 V. Electrical submersible pump has two components. The surface components and the sub-surface components. The surface components comprise of the motor controller (variable speed controller), surface cables, and the transformer. The sub- surface component consists of the pump portion and the motor portion. A high voltage of 3 to 5 KV ac source at the surface drives the sub-surface motor. The motor used to drive the pump is three phase squirrel cage induction motor. The motor driver used is L293D which can be connected to two motors.

2.4. THINKSPEAK application programming interface

An API is a contract provided by one piece of computer software to another. They are basically blocks of code that helps in communicating with either hardware or software. APIs are set of programming instruction and standards for accessing a web- based software application or web tool are readily defined in a web-based API. APIs are the browsers that we use to browse the internet, commercially used APIs such as you-tube API and the Google maps API. The API keys are

- To be able to access data from API we need API keys.
- API key is a code passed in programs calling an API to identify the calling program, developer or user.
- API keys are based on the UUID systems (Universally Unique Identifier).
- API key is unique to each user and act as a secret token for authentication.

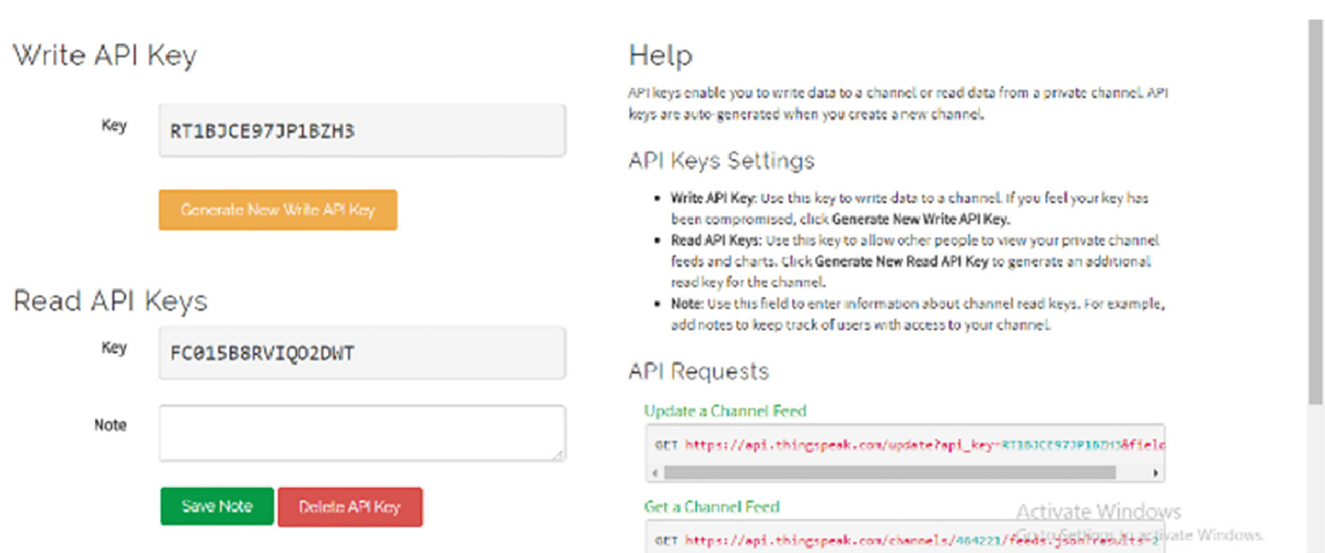

Fig. 5. API read and write keys for the THINKSPEAK channel.

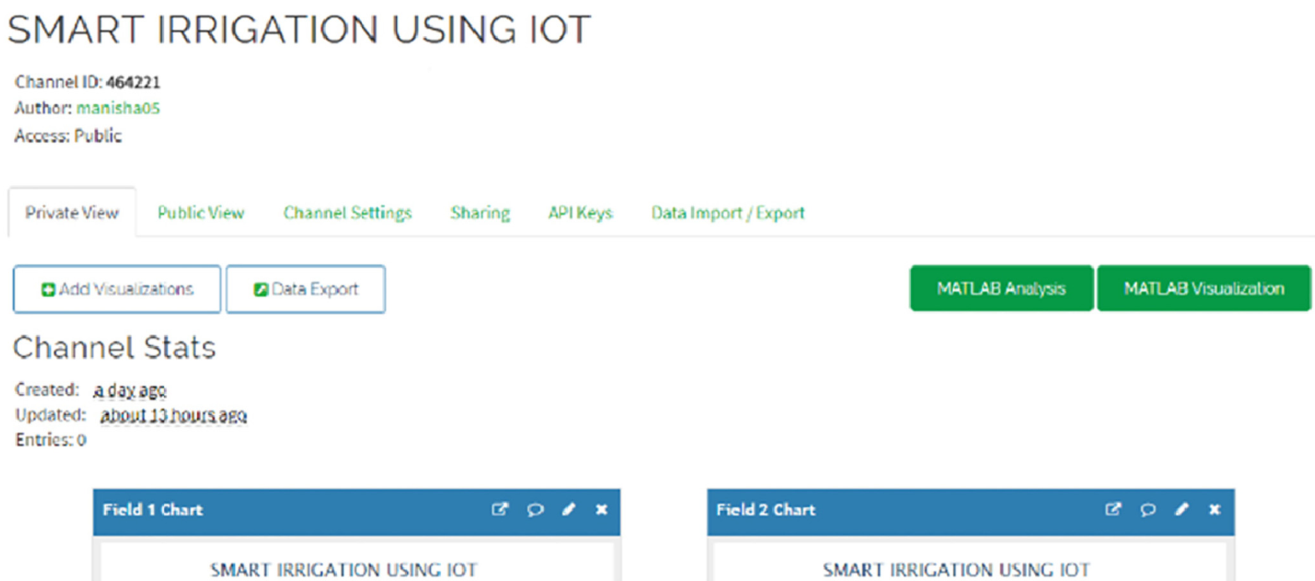

Fig. 6. API THINKSPEAK channel – created with ID 464221.

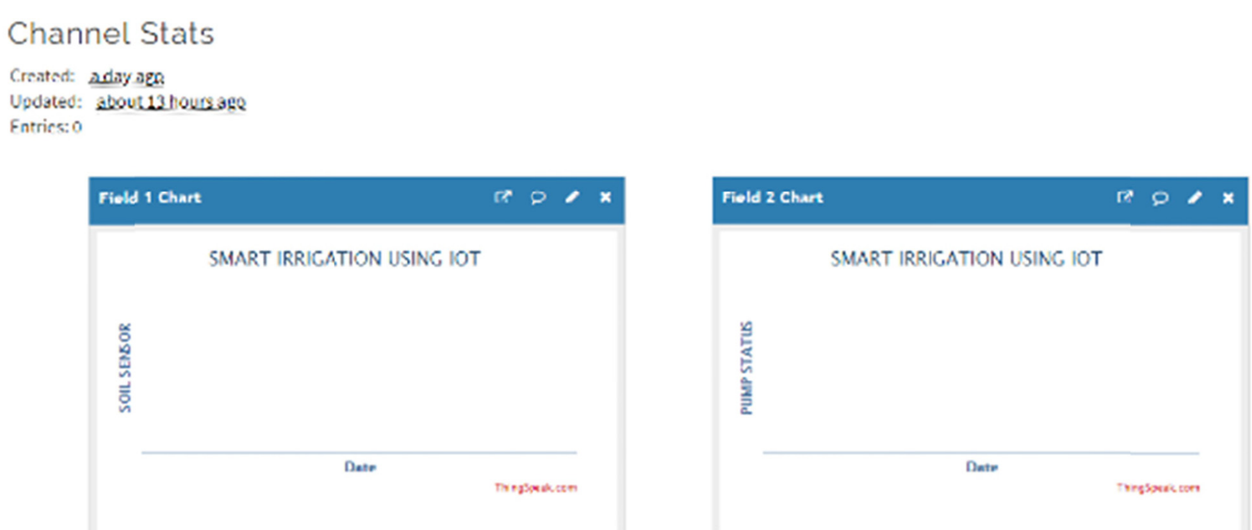

Fig. 7. API THINKSPEAK channel – monitoring the soil moisture and pump status.

Table 5
Real time data sensing.

Colour	Indication
Red	Calibrated Mapped Values Of Sensor For Loamy Soil
Black	Values When The Probe Is Exposed Various Depths Of Soil
Blue	Values When Probe Is Not Exposed To Soil Or Has Residual Soil Stuck To The Probe
Sensor Data 85, Sensor Data 85, Sensor Data 72, Sensor Data 64, Sensor Data 25, Sensor Data 0, Sensor Data 61, Sensor Data 61, Sensor Data 0, Sensor Data 0, Sensor Data 86, Sensor Data 84	

Table 6
Serial communication by ESP-8266.

Hayes or AT command	Function
AT + CWMODE = 1	Sets the Wi-Fi to station
AT + CWLAP	Lists all the available access points of Wi-Fi or hotspots
AT + EWJAP="SSID",'PASSWORD"	Joins the access point/Wi-Fi network with the given SSID and PASSWORD
AT + CIPSTART	Setup TCP/IP connection to send data
AT + CIPSEND	Sends data over the TCP/IP connection
AT + CIFSR	Gets the IP address of esp-8266 assigned by the access point

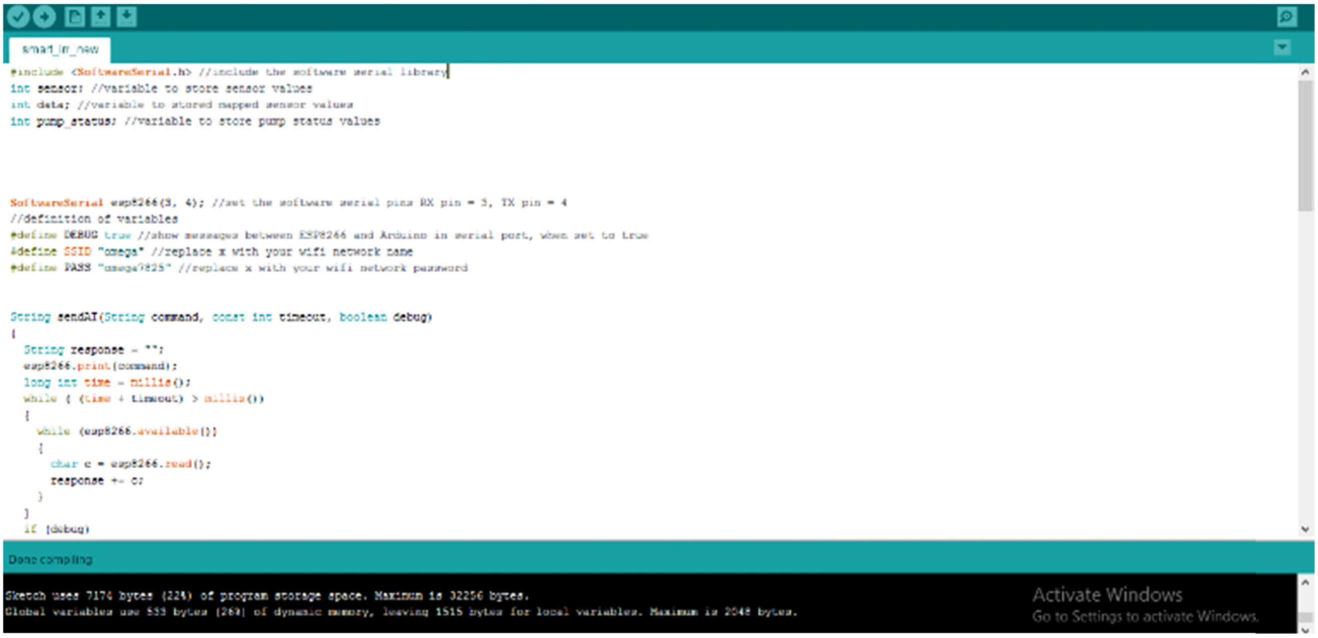

Fig. 8. Arduino IDE 1.8.4 – Preview.

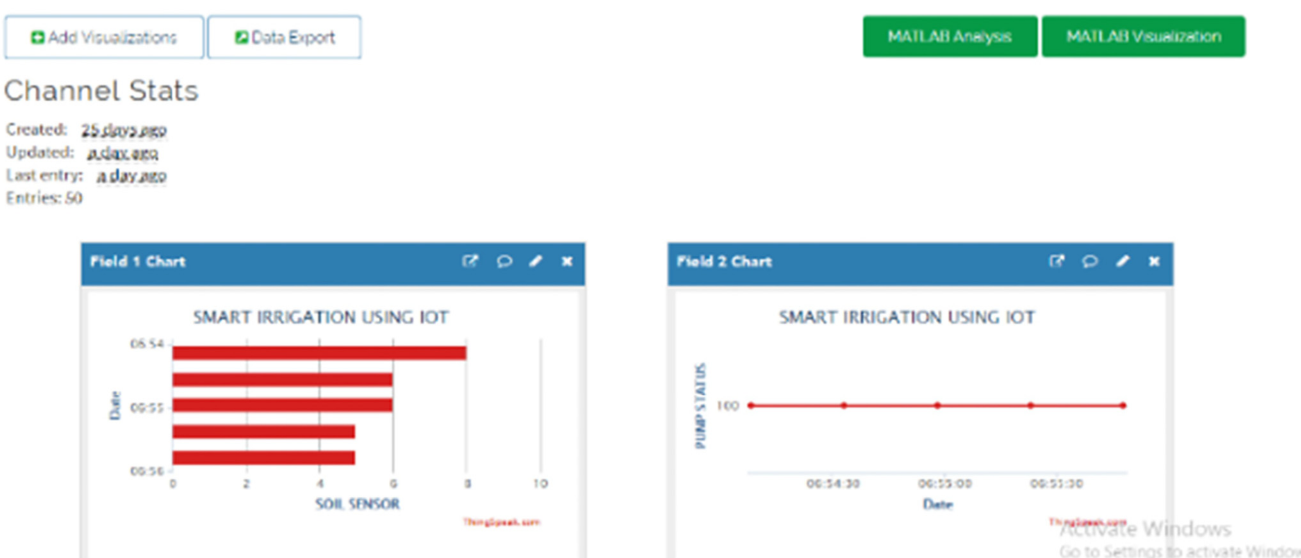

Fig. 9. Commands check.

THINGSPEAK APP has been used to display historical data that the moisture sensor reads and the pump status. Thinkspeak app account can be created using the email id, a channel is created for the IOT, two fields have to be created for the sensor and pump status, while the read API keys are used to read data from the channel, the write keys are used for sending or uploading a data to the channel as shown in Figs. 5–7. These keys are helpful for setting up the Virtuino app account in the phone. Arduino and virtuino app were connected via multiple communication channels like Bluetooth web or IOT Thinkspeak, IOT server was added, read and write key credentials were added along with the channel number. A refresh time of 15 s and moisture level limits were fed. Thus the virtuino app was set up and the Arduino sketch for the prototype, as uploaded in the Arduino Uno r3 board via COM port 6 and baud rate of 9600.

2.5. Experimental method developed to capture soil moisture data

The developed experimental methods may be summarized. Several soil samples were collected for analysis of moisture content during normal sunny day and was tested using the calibrated soil moisture sensor module and viewed on the serial monitor of Ardu-

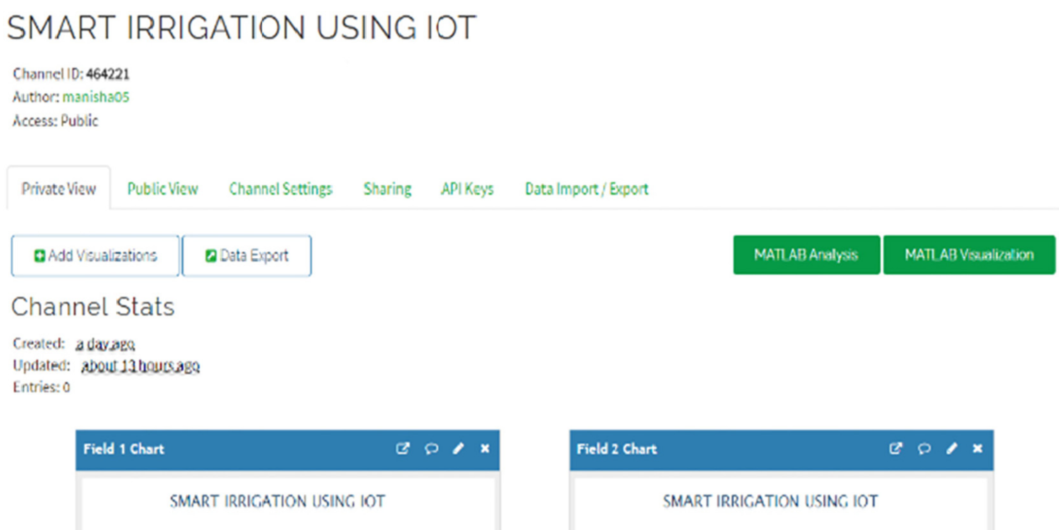

Fig. 10. THINKSPEAK channel setup.

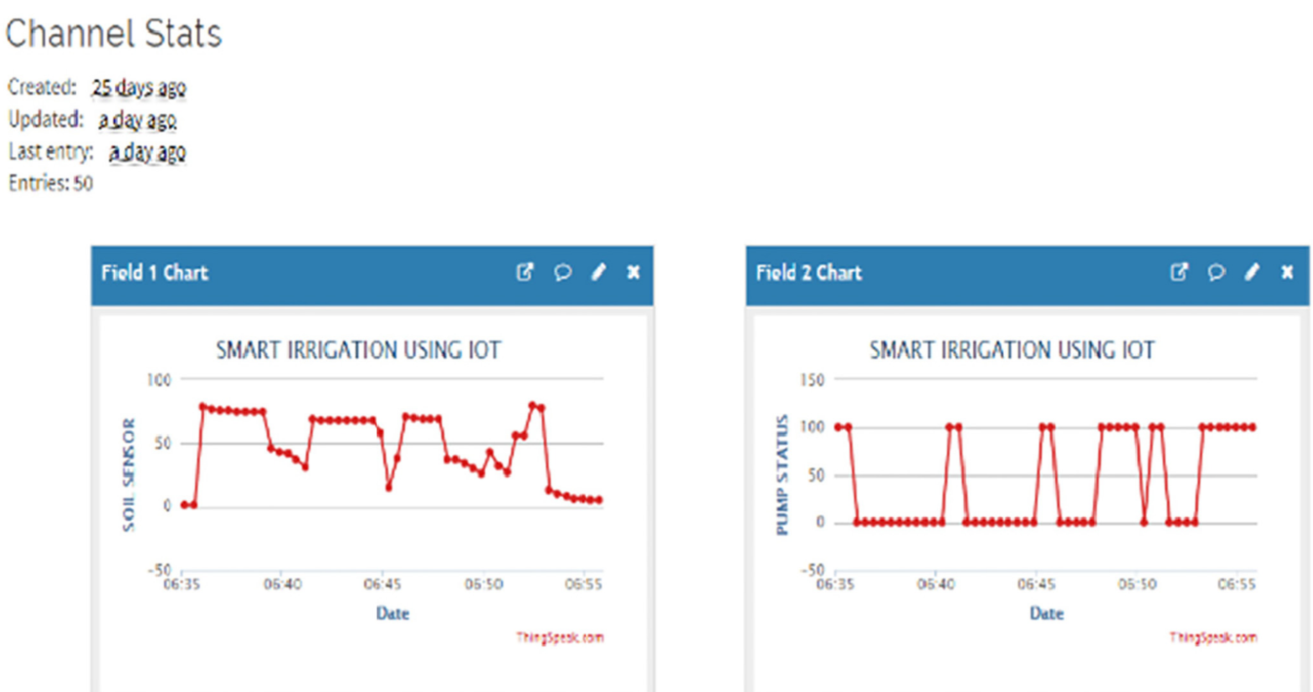

Fig. 11. Private mode result display.

ino ide 1.8.4. The list of first 12 real time data sensed by the soil moisture sensor and displayed on the serial monitor of ARDUINO IDE 1.8.4 are furnished in Table 5 and 6. The detailed step-by-step approach of the system is depicted from Figs. 8–15.

Pump working was checked.

The main program was uploaded in the Arduino Uno r3 board and the serial monitor was set to a baud rate of 9600 and was checked for any errors.

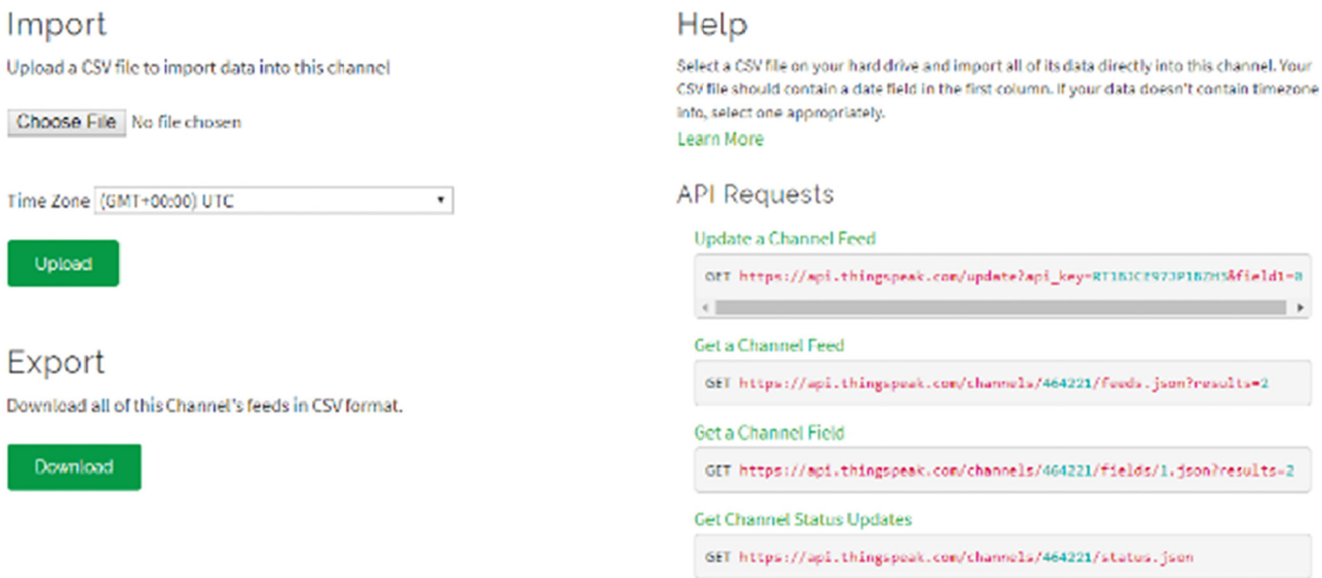

Fig. 12. Real time data interpolation.

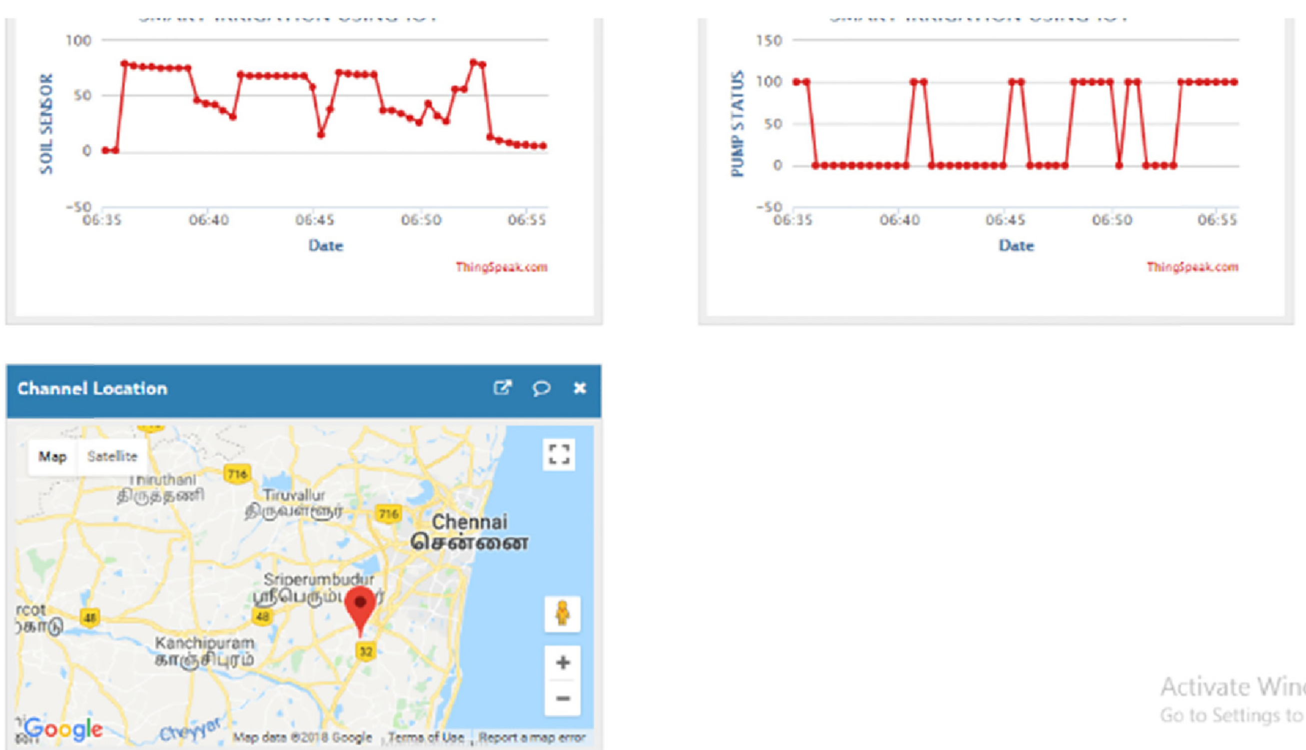

Fig. 13. Location identifier.

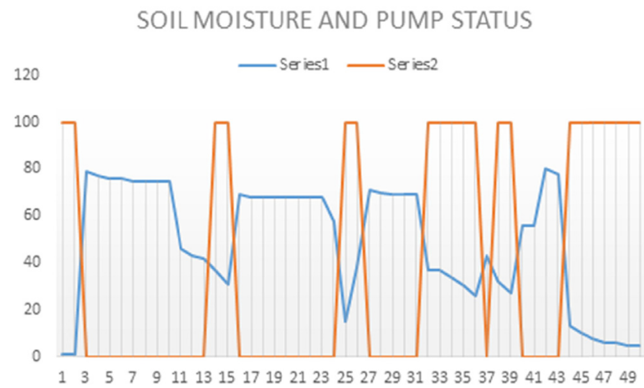

Fig. 14. Outcome of THINKSPEAK channel.

Thinkspeak channel was created and the real time data sensed by the soil moisture module was observed on the PC and mobile screen.

3. Conclusion

This experiment was taken up to build an IoT based application for sustained farm practice by sensing the soil moisture from the soil using the soil moisture sensor module, communicating over internet by the ESP-8266 Wi-Fi module that controls the switching of the submersible motor pump (motor driver-289D) via Arduino uno r3. The communication request was successfully created by the computer on the given web page of THINKSPEAK APP from the server which further displays the real time sensor values and the pump status in a graphical form. The prototype was successfully designed and tested to sense the real time soil moisture values, send it to the Arduino via the serial communication over the ESP-8266 Wi-Fi module that further plots this value on the created Thinkspeak channel and is made user-friendly via using virtuino app in the mobile, which enabled the remote monitoring the soil moisture values and thus assisting the control of the water pump. All the parameters and working of the devices were successfully tested in real time for chilli crop in a farm. The IOT based smart agriculture is a breakthrough in the agriculture sector that gives better solution for water conservation, reduces labor cost, electric-

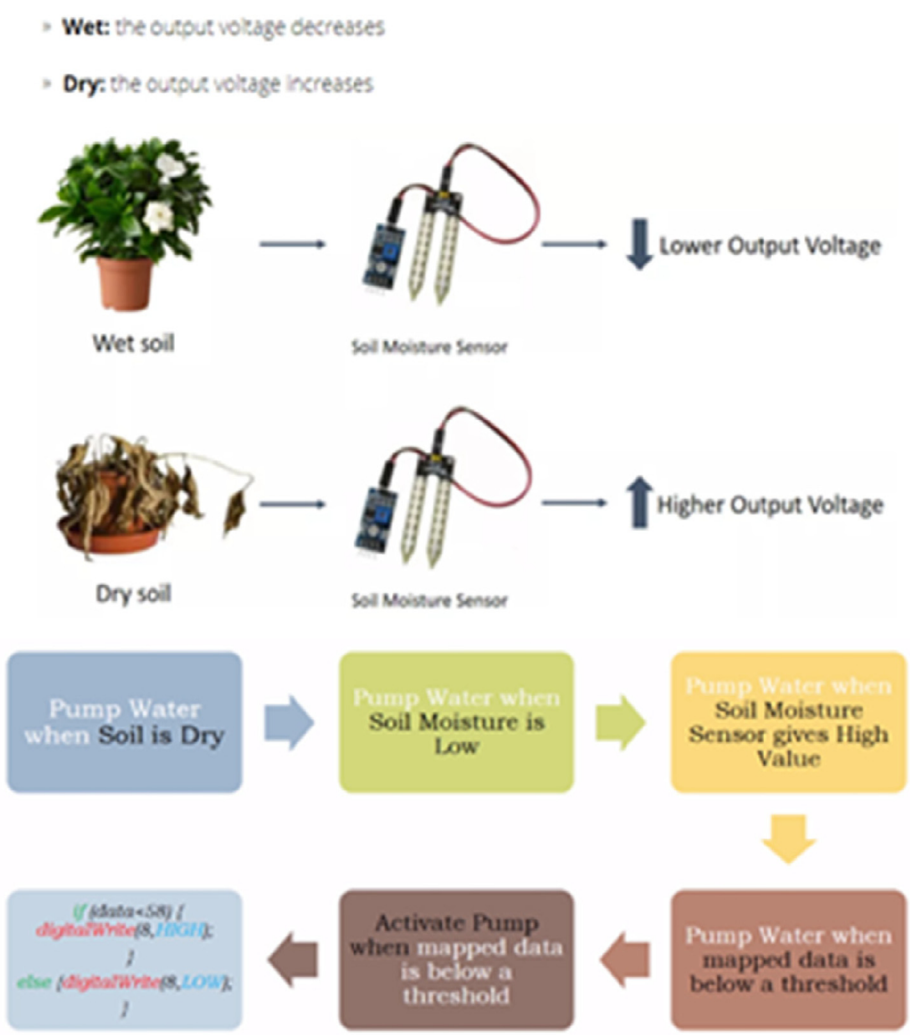

Fig. 15. Irrigation pump working with auto cut-off.

ity conservation and helps the farmer to keep a record of his yields throughout the year on a wireless mode. This study is a successful attempt in this direction.

CRediT authorship contribution statement

K. Nanda Kumar: . : Conceptualization, Data curation, Formal analysis, Investigation, Methodology. **Adarsh Vijayan Pillai:** Project administration, Writing - original draft. **M.K. Badri Narayanan:** Resources, Writing - review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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