System Architecture for the Internet of Things (IoT) Based Smart Agriculture Monitoring

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***Abstract*—The Internet of Things (IoT) refers to a collection of billions of physical devices across the globe that are linked to the internet. The Internet of Things is making our life smarter and more approachable by merging the digital and physical world. The issues concerned with the field of agriculture are pestle and animal attacks on the crops, unawareness of weather conditions, manual irrigation systems, and lack of monitoring and controlling of farms remotely. Thus, IoT is a cost-effective solution to overcome these major problems. It plays a major role in developed countries but in progressive countries like Pakistan, where agriculture is the backbone of the economy, old cultivation methods are used which results in low production. The main features of our proposed IoT architecture include pest monitoring, temperature, humidity, soil moisture, and watering control. All the sensor data is gathered at a monitoring hub via a wireless network. The additional features of the proposed architecture are the Global System for Mobile Communication (GSM) and the Virtual Network Computing (VNC) viewer where users can control the sensors remotely from anywhere in the world. All the desired data and alerts reach the farmer by GSM or through Thing Speak in Graphical form and previous data is saved on the Thing Speak cloud. This IoT-based proposed architecture is deployed on the farm, and it is cost-effective as well.**

***Keywords*—IoT, Smart Agriculture, Smart Farming, Remote Monitoring, Real-time agriculture monitoring.**

INTRODUCTION

Pakistan is an agricultural country, and it is the primary sector of the country's economy. But unfortunately, farmers are still unaware of advanced agricultural techniques and practice conventional methods, resulting in low yield and financial loss. Also, several factors contribute to the low yield of crops such as proper soil preparation, seed rate, seed cultivator, different sowing time, lack of application of fertilizers, plant protection, adoption of modern technologies, improper marketing, and lack of investment. Such issues are only resolved by implementing contemporary technologies and advanced monitoring systems. Internet of Things (IoT) almost transforms every sector of life. The Internet of Things (IoT) is a generic word for a unique perspective when the actual Internet is reached with physical objects and sensors.

The major benefit of IoT systems is that they can provide a centralized point to control all the physical and portable devices that are connected to your network, and this centralized control point can be programmed to do specific tasks related to the owner's demands. In the field of IoT, Wireless Sensor Network (WSN) plays a vital role. It comprises a wireless group of a combination of electronic devices such as sensor devices that can communicate with each other or with the internet cloud. It records the data wirelessly from a monitored or desired field. In WSN technology wiring issues are resolved along with the accommodation of new devices saving cost and time, cheaper methods, and very useful to the advanced world. In [1] author proposes smart agriculture using a microcontroller, and a decision is made. Blynk app is used for notification and reading. In this system, water is conserved by an automated system using a microcontroller. In [2] author proposes the uses of various sensors and the GPRS (General Packet Radio Service) module and uses the GSM module to send messages and the website is used for IoT notification. In addition, it uses buzzers, relay, ADC converters, etc. It uses Proteus 8 for the microcontroller circuit designs. In [3] author introduces low-power Bluetooth and low-power wide area network to develop a smart farm. The system contains several nodes, databases, gateways, servers, and smartphones. The bit loss problem is addressed using a standardized message exchange method as an alternative to prevent bit loss caused by message transmission using a wireless communication module from a node to a gateway. In [4] author introduces the concept of a smart irrigation system that optimizes water usage and reduces labor costs. Moisture sensors are buried into the soil which notifies the system. Arduino kit is used with moisture sensor and with WI-FI kit. C-Language is used to decide on water closure and in this way, the usage of water is optimized and hence it greatly reduces the cost of irrigation. In [5] author proposes an automated system for irrigation that observes and controls water requirements. The database is updated timely.

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To perform this automated irrigation system, micro-controller and android systems are used. In addition, to take decisions web scrapers, Arduino studio, and MY SQL is used in the proposed system- In [6] author proposes real-time soil monitoring using soil factors like humidity, moisture, etc. Nodes are spread in the crop area and data transfer takes place from nodes to server. For alerts, a decision support model is implemented. To receive the alerts web application and mobile application is introduced on the user end. In [7] author proposes a new topology mechanism for sensor nodes, the proposed system optimizes power usage and provides a solution to real-time monitoring. Lower power is consumed by the system, and it continually monitors the data and communicates with the user via mobile and network applications. The proposed system uses a microcontroller module, WIFI module, temperature sensor, soil moisture, rain sensor, and water level monitoring sensor. In [8] author proposes monitoring environmental factors which affect the agriculture system. Temperature and humidity are monitored by a chip CC3200 in the agriculture field. Images of the field are captured by the camera, which is interfaced with CC3200, and the images are sent to the user as Multimedia Messaging System (MMS) using WIFI to keep the farmers updated with temperature and humidity readings. We proposed the IoT-based framework in agriculture for the facilitation of farmers in the field without any physical intervention. The scenario is based on sensed values that have been recorded or analyzed Sensed values are recorded through temperature and humidity sensor (DHT11), Passive Infrared (PIR) sensor, Soil moisture sensor, and Global system for mobile (GSM) module. The main objective of this proposed architecture is to provide automatic irrigation facilities through the water pump and soil moisture sensor, Intruder alerts, and live monitoring of temperature and humidity that helps the farmer to protect their crop according to the environment. GSM is an extra feature that provides a live update to a farmer's mobile if the internet cloud becomes down so the farmer is aware of his farm. All these data are sent to the IoT-based cloud server Thing Speak. It can be accessed through the website which passes information to the management model using cellphone and computers. If any changes are required in the system so that a person can get access to Raspberry Pi through a remote location by using Virtual Network Computing (VNC) application. This paper is organized as follows. Section II represents the related work with the existing proposed architecture. Section III represents shows the design and Implementation of work using Raspberry Pi3 Model B. Section IV presents framework implementation and its result. In the last Section V elaborates on the conclusion.

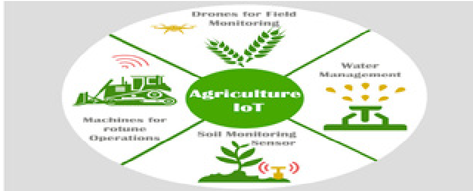

Fig 1: Major IoT Applications

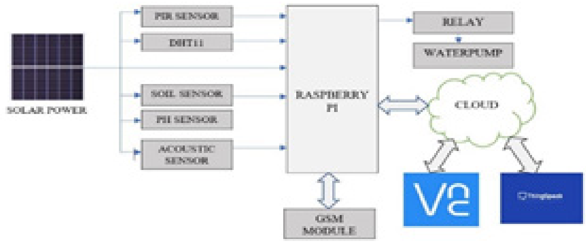

Fig 2: The framework of the proposed work.

RELATED WORK

In [9] author proposes framework for smart agriculture filed monitoring. The framework is designed to obtain real time data. The proposed system predicts the upcoming weather and allow farmers to take decision. The measured parameters like temperature, humidity is stored on cloud-based environment for further data analysis and predictions. In [10] 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 author proposes a real time soil moisture system to measure soil moisture values and send to Arduino over Wi-Fi module that controls the motor pump via Arduino uno r3. Using the designed system for agriculture all the parameters and working were successfully tested for chili crops in real time. In [11] author proposes IoT based system for monitoring of corn fields using drone and IoT. The scheme has several sensor nodes, coordinator nodes and gateway. The drone is used to periodically collect information from the coordinator node and forward it to the gateway node. The delay and throughput results are analyzed. The delay from packet generation time to gateway arrival time is calculated according to the location of the sensor nodes, gateway nodes and drone altitudes. The proposed system is capable of sensing PH levels, temperature, humidity etc. of the cornfields. In [12]everywhere, we have seen the manifestation of locust outbreaks and how humans have fought against it for their survival generations after generations. The latest locust eruption began in June 2019 and has continued through 2020. It has been the worst one in the last 70 years in Middle Africa, Middle East, South Asia, and South America. Countries are taking precautions to be safe from this outbreak because, after this corona pandemic, no nation is willing to face another economic pandemic. In advances of facing the consequences of the locust swarms, we need to find an effective and smart solution. In this paper, we have come up with the idea of monitoring important agricultural factors such as soil moisture, temperature, and humidity using sensors to provide real-time information to the farmers about imminent locust infestation to their mobile. Also, to ease their work, our proposed system will provide water and pesticides automatically to the fields by using Raspberry Pi and Node MCU. Our proposed system will generate ultraviolet light and loud noise to kill the insects in case of a locust outbreak. As locust's habitats are closely related to different agricultural factors, linear regression, logistic regression, and support vector regression, machine learning algorithms have been implemented to predict the temperature and humidity so that the farmers can anticipate these factors well ahead of time and plan accordingly. Overall a next-generation solution to fight the locusts has been implemented in this paper.","container-title":"2021 8th International Conference on Information Technology, Computer and Electrical Engineering (ICITACEE author proposes IoT based smart agriculture system which can prevent locust attack by generating ultraviolet light and loud noises to kill insects incase of locust outbreaks. Next generation solution like machine learning concepts is used to predict temperature, humidity values so that farmers can plan and take timely decisions to save the crop from insect attacks. In [13]temperature of surrounding environment, and status of motor regarding main power supply or solar power. Fuzzy logic controller is used to compute input parameters (e.g. soil moisture, temperature and humidity author proposes fuzzy logic based scheme to control motor status using soil moisture, temperature and humidity as input parameters for fuzzy logic system. It also saves water according to field parameters. MATLAB and Arduino programming is used to collect information about these parameters. In [14] author proposes intelligent irrigation system using the concept of neural networks with four input parameters temperature, plant growth, humidity, and soil moisture. Based on the values of input parameters decision is taken to control water supply and fertilizer spray. The proposed system is useful for greenhouses and home gardening. In [15] proposes a mobile information system for smart irrigation so that proper information reaches the farmer about weather conditions so that they can make proper decisions. In [16] uses prediction models such as principal component analysis and neural network classification techniques are used for crop productivity predictions to enhance. The proposed model can make more accurate decisions based on predictions. In [17] author propose low-cost weather stations for precision agriculture to make traditional agriculture more profitable. The proposed scheme helps farmers to take real-time decisions which helps in the efficient utilization of agriculture resources. In [18] proposes a smart farm idea. The system consists of three main components which include hardware, web application, and mobile application. Hardware is used to collect the data from the crops, the web application is designed for collecting crop data and information, and a mobile application is used to control crop watering using a mobile application to efficiently utilize resources. In addition, the system is also capable of sending notifications via line API. In [19]Internet of Things (IoT author proposes an Internet of Plants-based system application that can monitor the temperature, humidity, and soil moisture of plants. It also aids a predictive neural network model for temperature forecasting. In [20] author proposes a decision support system for late blight diseases which occurs in potatoes. Temperature and humidity information is obtained from sensor networks and stored in cloud. The decision support system notify farmers in case of attack which can help in disease prevention.

PROPOSED SYSTEM

The system is communicating with the server through Wi-Fi because Raspberry Pi only connects with the internet through Wi-Fi or USB internet. All sensed data is posted to a server for monitoring of data in this proposed architecture manual controlling is not required. The same process occurs in the VNC server. This Proposed architecture model is based on three factors.

Monitoring

This proposed architecture aims at Real-time monitoring of farms. For farm monitoring, we use DHT11 for temperature and humidity, PIR sensor for motion or intruder detection and soil moisture sensor for sensing the real-time condition of the soil to start or stop water pump for irrigation with Raspberry Pi through Wi-Fi or hotspot all sensed data is sent to ThingSpeak server and GSM module sending data to mobile phone for monitoring of data.

Surveillance

In this heading surveillance or alerts are discussed. Live monitoring of data through GSM or Thing Speak is already happening but an extra feature of this proposed architecture is alarm or surveillance through buzzers. The main purpose of adding a buzzer is to alert the farmer if he is present on the farm. Two buzzers are used for 2 different surveillance cases.

- If an intruder is detected on the farm buzzer starts.
- If the soil needs water buzzer starts ringing to alert the farmer that the water pump is on.

Automatic controlling

In this proposed architecture, no one is present to monitor the farm. The circuit can do automatic irrigation if the farm required water. Automatic alerts are sent to the farmer through GSM and an alarm system that is fixed if some intruders are detected. No middleman is needed to do monitoring and sends alerts to the farmer.

HARDWARE DESCRIPTION

Raspberry Pi 3 Model B

Raspberry Pi3 Model B is the 64-bit latest model. It is developed in 2016 in the replacement of Raspberry pi2 model B. It has Broadcom BCM2837 SOC (System on Chip) along with Quad-core ARMcortexA53 CPU. It operates at a speed of 1.2 GHz. It is an integrated circuit that performs the function of integration of all components. It has external data connectivity and the gateway to interconnect with any physical devices or with the internet.

Fig 3: Raspberry Pi 3 Model B Passive infrared (PIR)

A passive infrared (PIR) sensor is also known as a pyro-electric sensor or IR motion sensor. Each and everybody on the earth emits some heat energy as they move. Some emit low heat energy, and some emit high heat energy in the form of radiations dependent on how hotness level. The heat radiation is infrared. PIR sensor is used to detect those infrared radiations which notify the detection of movement of animals, people, or any other object in the required region. A PIR sensor is made up of two slots that comprise IR-sensitive material. If there is no motion in front of these two slots, it measures the same IR level and if there is motion the two slots detect the change in IR level. This change in IR level is detected by the PIR sensor.

Fig 4: Passive Infrared Sensor

Soil moisture sensor

A soil moisture sensor is used to measure the moisture content of the soil. It has both the output which is the analog output (threshold can be varied) and digital output (fixed). Soil. The moisture sensor is platinum-coated so that its efficiency is high and also its sensing range is high. It consists of two rods-like probes that measured the volumetric content of the soil. Soil moisture sensor works on the principle of open circuit and short circuit. When the soil is dry, it will not allow the current to pass and thus the output is maximum. This circuit is said to be an open circuit. When the soil is wet, it will allow the current to pass and thus the output is zero. This circuit is said to be a closed circuit. Soil moisture sensor also works on the principle of dielectric constant which is an electrical property that depends on the soil moisture content. As the dielectric constant increase, the water moisture level also increases.

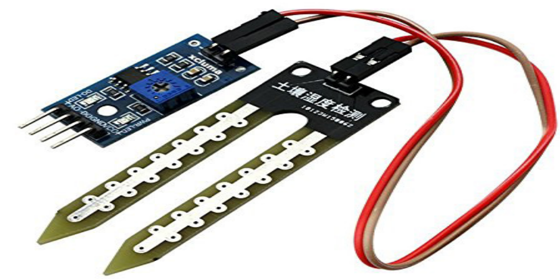

Fig 5: Soil Moisture Sensor

DHT11 sensor

DHT11 is used to measure both the temperature and humidity values. It is a low-cost, reliable sensor and highly stable. It has the temperature sensing element and the humidity sensing element. Both elements are made up of semiconductor material. The humidity sensing element consists of two electrodes for sensing the air moisture. As the moisture changes, the resistance will be changed, and the air moisture will be sensed. The temperature sensing element comprises a negative temperature co-efficient element meaning that as the temperature increases the resistance will be decreased.

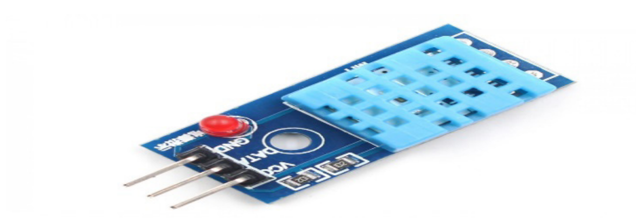

Fig 6: DHT11 Sensor

Sim 800L

SIM800L GSM module is an ultra-reduced and dependable remote module. The SIM800L may be a total Dual-band GSM/GPRS arrangement to an SMT module which could make embedded in the client requisitions enabling you will benefit from minimal estimations furthermore savvy solutions. Featuring an industry-standard interface, the SIM800L conveys implementations to voice, SMS, data also fax in a little shape factor, also for low power use. For a small setup of 23mmx35mmx5.6mm, SIM800L can fit every one of the space prerequisites in your applications, especially to slim furthermore reducing the outline request.

Fig 7: SIM 800L

Relay

It is the switching-like device that automatically controls the high current circuit with the low current circuit. It is widely used in switching circuits, automatic circuits, remote-controlled circuits, safety circuits, and various IoT-based projects.

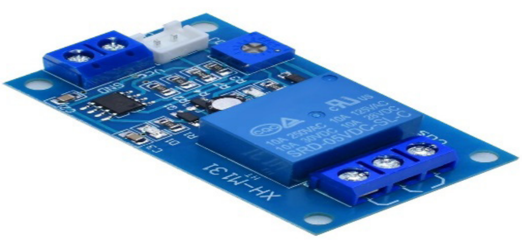

Fig 8: Relay

Water pump

A pump is a piece of equipment that moves fluids by automatic action. Pumps can manage by various mechanisms (usually reciprocating or rotary) and use energy to perform mechanical work by stirring the fluid. Pumps operate employing many energy sources, including manual processes, voltage, engines, or coil power, and come in many sizes from microscopic for use in medical purposes to large industrial pumps.

Fig 9: Water Pump

Buzzer

A buzzer is a small portable electronic device that consists of two terminals that is the positive terminal and the negative terminal. This electronic equipment is added to the proposed architecture for the alarming purpose of adding sound features.

Fig 10. Buzzer

Acoustic Sensor

To enhance plant quality, detection of sounds from bugs and rodents in the crop is very important. To achieve this acoustic sensor is used and installed at random locations around the crop area. In case of sound, detection farmers can spray pesticides on these sites to ensure the quality of crops. This effective method offers accuracy in detecting pest infestations. The accuracy of these sensors reduces considerably under rainy conditions.

Fig 11. Acoustic Sensor

SOFTWARE DESCRIPTION

There are multiple software playing a vital role in this system. Python is the center of all communication, surveillance, and monitoring.

Linux

The raspberry pi is based on Linux operating system which is open source. We used Raspbian as our operating system in our proposed architecture. It contains all the programs that we need to execute our task. It is considered a good learning operating system as we all know the main purpose of raspberry pi is to provide knowledge of computers in remote areas. All libraries are installed in the Raspberry Pi shell that is 49 completely based on the Linux command window environment and all programming languages libraries are associated with this shell. It means there is complete freedom to run the program for any purpose. It provides freedom to see how the program works and if users want the changes are also possible.

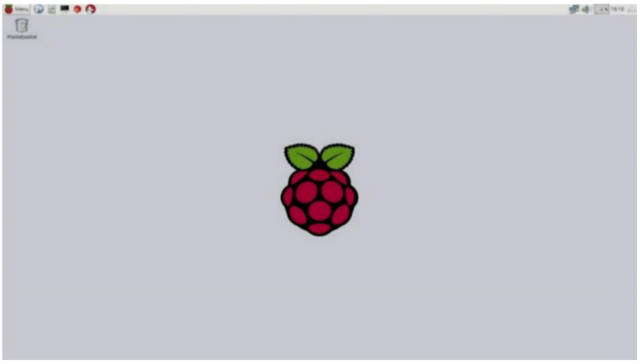

Fig 12: Linux operating system

Python

Python is a general-purpose language. It is a powerful and the most demanded programming language. The reason for its popularity is its syntax, readability uses its standards English keywords. Python is the only reason for electing the raspberry pi because working on this language beginner learns a new era of programming with less difficulty. Instead of selecting C++ java is its demand. In raspberry pi you enter Python through open IDE from the desktop menu you need to download libraries in a Raspberry Pi shell that is in Linux. We have used version 3 of python.

Fig 13: Python versions

Virtual Network Computing (VNC)

The VNC protocol is a simple protocol for remote access to graphical user interfaces. It is based on Remote Frame Buffer. This provides the user with the desktop base environment or the graphical base environment. It is easy because beginners understand and operate. To access VNC Raspberry Pi it is necessary to download VNC libraries or enable a VNC viewer.

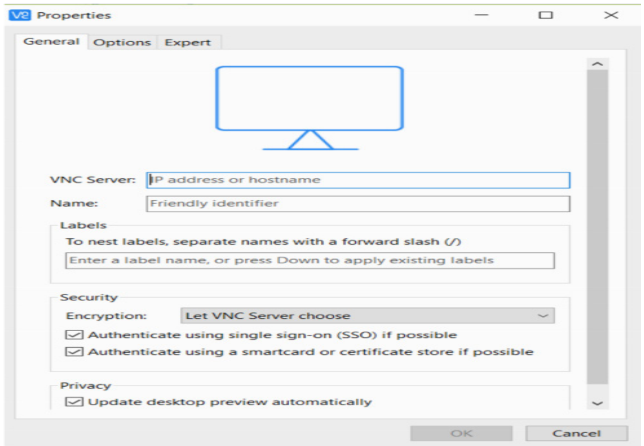

Fig 14: VNC Interface

ThingSpeak

Think to speak is an open-source Internet IoT application. This application collects the data from the sensor and stores data in the cloud at the Internet of Thing application. This application presents data in the form of a graphical way for analysis. The second reason for the friendly environment is it sends and saves sensor data on the cloud and provides easy visualization and analyze data.

IMPLEMENTATION

The following prototype is implemented in the agriculture field.

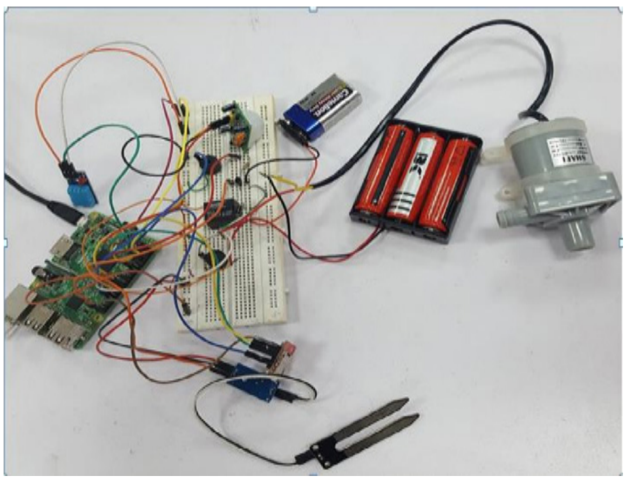

Fig 15: Implementation of the proposed scheme.

Python Shell

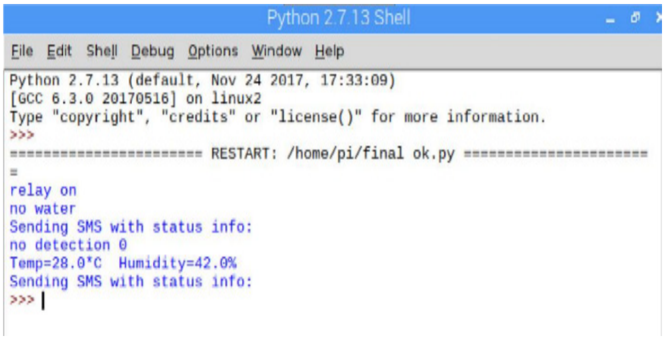

Fig 16: Python Shell

RESULTS & DISCUSSIONS

Fig 17: DHT11 Result

Figure 17 depicts the temperature of the field vs. date results from the DHT11 sensor, which is used to collect the data. The graph shows that various temperature readings are taken during the experimentation from August to October. It can be seen that temperature values are rising and reaching a high of 40 degrees in October. Temperature is an important factor in agricultural field monitoring because it can harm crops and reduce crop productivity.

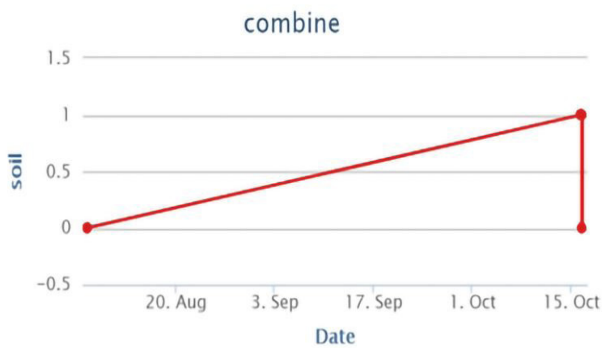

Fig 18: Soil Moisture sensor

Figure 18 depicts the relationship between soil moisture sensor and date; the figure shows that moisture tends to increase from August to October and then decreases after a certain point. Measuring soil moisture is also important for farmers to efficiently manage their irrigation. When the precise soil moisture conditions are known, it is possible to use less water to grow more crops. The crop's quality and yield can be improved in this manner. The relationship between soil moisture sensor vs date can be seen in the figure, which shows that moisture tends to increase and then fall after a certain point betweenAugust and October.

Fig 19: PIR sensor

Figure 19 depicts the results of PIR sensors installed in the agricultural field. During the experimentation phase, no animal or human object was seen at the agriculture site that could harm the farms. As a result, it has no value in the graph. PIR sensors also serve as a security feature in agriculture monitoring because they can alert farmers if anything harmful to the crops is discovered.

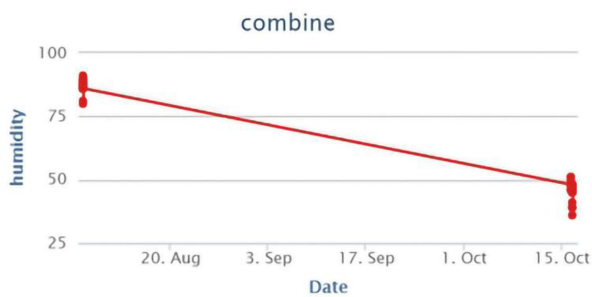

Fig 20: DHT11 Humidity Result

Figure 20 depicts the results of a humidity sensor from August to October, and it can be seen that the humidity percentage decreases as time passes from August to October. Humidity is an important factor because it indicates the concentration of water vapor in the air. As a result, this factor is also critical in agricultural field monitoring.

The additional feature of this research project is, that it informs all the parameters of the farmers through GSM, and in addition, it also works as a water-saving project. Because it turns on and off the relay to turn on and off the motor according to the threshold value of the water which is observed in the field. From Figure 21 it can be seen that when the relay is on it shown an intruder is detected and it shows no detection and sends the value of temperature and humidity to the farmers.

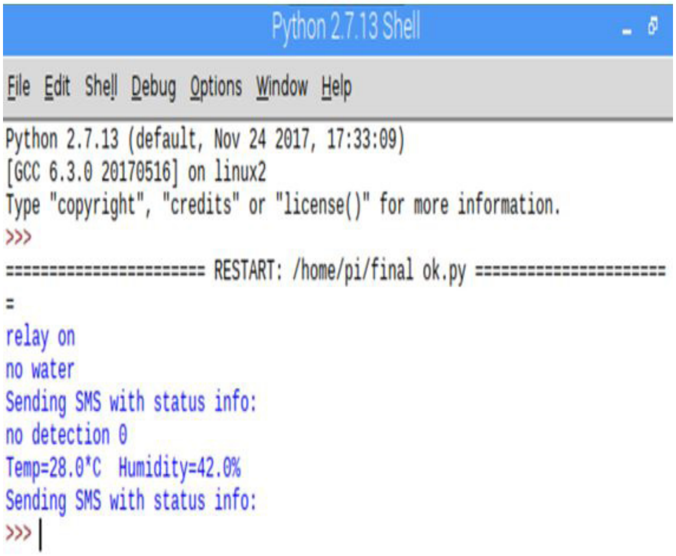

Fig 21: ThinkSpeak Results

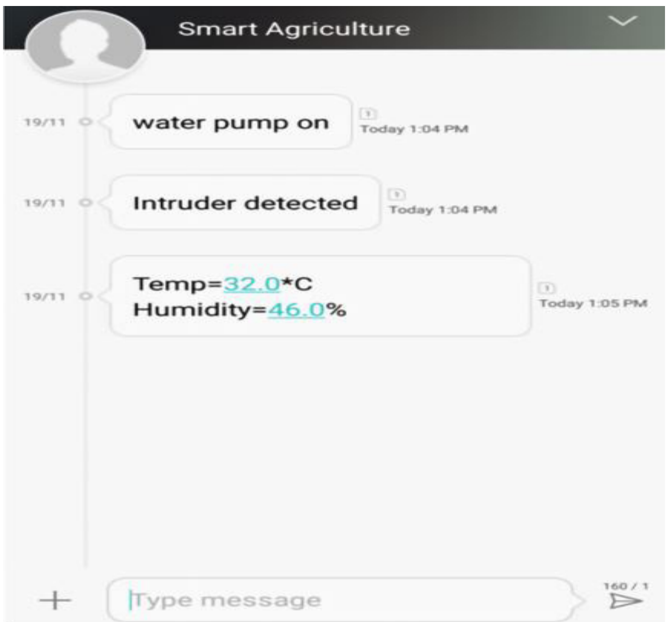

Fig 22: VNC Results

CONCLUSION & FUTURE WORK

IoT-based Smart system is feasible to use these days. As it plays a vital role in Pakistan´s economy now and in the years to come. This system increases productivity as well as improves the quality of crops by usages of IoT technology in the system. The implementation of the IoT technology is the need for the agricultural process to make it easier and burden-free for farmers. This system which we have designed is very cost-effective and consumes less time. Two main issues related to agriculture i.e., monitoring, and remote controlling have been addressed. For monitoring purposes, we have used a cloud-based server which is ThinkSpeak of IoT platform from which data analysis and remote controlling are done through an android app which is VNC viewer. The system is capable of reading and giving results on the data analysis and from the usage of different sensors to secure the system from pests, checking the water level in the soil, and sensing the humidity and temperature conditions of the environment. The additional feature of the system we designed was GSM interfacing which will send text messages in case of emergency. The IoT-based smart platform will ease the life of farmers in the future but also the smart systems will spread in form of vertical farming which will not only reduce the space but will contribute economically to society. The scope of this work is limited and can further be enhanced in the future by identifying crop diseases, identifying damaged areas by natural disasters, rainfall status, and several different crops in the area. In addition, to get complete benefits from agriculture monitoring a greater number of sensors can be interfaced with microcontrollers to get the maximum utility of the farms this includes $C0^2$ sensors, PH sensors, and GPS sensors.

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