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DESIGN & IMPLEMENTATION OF INNOVATIVE IoT BASED SMART AGRICULTURE MANAGEMENT SYSTEM FOR EFFICIENT CROP GROWTH

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***Abstract*— India is a land of agriculture. With rapid population growth and increasing food demand, boosting farm productivity and yield is essential. More than 70% of the population is involved directly or indirectly in crop production activities. This sector contributes to the Indian economy a great deal. It contributes over 17% of the total Gross Domestic Product (GDP). With the introduction of newer seed varieties, new methods of agriculture, and the use of efficient fertilizers, crop production has increased. But without using the smarter methods, the agricultural domain still remains in the backlogs. The conventional method involves a lot of human instincts which at times fail. And thus there is a need for a smarter way of crop production using Internet of Things (IoT) and Machine learning techniques. The proposed system is a smart agriculture management system (SAMS) which is automated to help farmers to increase the crop production. The system also helps in reduction of resource wastage by adopting a technique called precision agriculture. The system uses different sensors for data acquisition to measure various environmental factors which are required for crop production. The data obtained from these sensors is visualized in the form of graphs. Smart agriculture is a farming system which uses IoT technology. This emerging system increases the quantity and quality of agricultural products. IoT devices provide information about nature of farming fields and then take action depending on the farmer input. In this paper, an IoT based advanced solution for monitoring the soil conditions and atmosphere for efficient crop growth is presented. The developed system is capable of monitoring temperature, humidity, soil moisture level using NodeMCU and several sensors connected to it. Also, a notification in the form of SMS will be sent to farmer's phone using Wi-Fi about environmental condition of the field. The system uses a network of several NodeMCUs (ESP8266) micro-controllers to monitor and control multiple systems over the cloud. The NodeMCUs constantly monitor the respective states of various elements of the farm and report the data to the central control unit. The user can then take appropriate actions from analyzing this data, i.e. assign their desired tasks to each of the micro-controllers separately.**

***Keywords*— IoT, Machine Learning, Precision Agriculture, Data Acquisition, Crop Prediction, Soil fertility, Sensors, Microcontroller, control system, load management, water management, irrigation.**

1. INTRODUCTION

With the recent development in the field of IoT, Big Data, Cloud and Mobile Computing, the world is moving towards smarter implementations to real-world problems. If speaking about the Indian context, agriculture happens to be the backbone of this developing nation's economy, making a transition from conventional agricultural methods to a much better and smarter method of agriculture will change the current scenario invariably. Improper maintenance of the crops leads to crop failure which in turn leads to huge loss for the farmers. Smart agriculture can thus help farmers in this aspect and make sure the economy of the country is improved when considered on a large scale. Smart agriculture employs a technique called precision farming where all the environmental aspects required by the crop to grow are constantly monitored. Monitoring alone cannot help the health of the crops and thus controlling these aspects if possible is also required. Besides, all this data is preserved and can be used for further prediction of the best suitable crop to be grown in that particular environment. The concepts of Machine Learning, IoT, Cloud computing can be used to develop a solution for this issue. The system uses different sensors to collect data required for the growth of the crop. The sensor data is also fed into Thing Speak IoT Cloud platform for data visualization. The data is also stored in real time on Firebase Database. This data is then used for crop prediction. The prediction module uses Support Vector Machine (SVM) classifier for prediction. The system is able to predict the top three best suited crops. Agriculture is the primary occupation in India and is the backbone of Indian economic system. Agriculture provides employment opportunities to rural people on a large scale in underdeveloped and developing countries in addition to providing food. It is the process of producing food, fiber and many other desired products by the cultivation and rising of domestic animals. Climate changes will have significant impact on agriculture by increasing water demand and limiting crop productivity in areas where irrigation is most needed. Irrigation system, rain fed agriculture, groundwater irrigation are some of the methods introduced to produce healthier crops which may not use water efficiently. In order to use water efficiently a smart system is designed. In the system farmer need not make the water flow into fields manually, but the system automatically does that efficiently. The traditional methods practiced by people may result in huge wastage of water. Hence, the concept of robotized farming with mix of IoT has been developed. The technological advancements began to increase the efficiency of production remarkably thus, making it a reliable system. The knowledge of properties of soil determines the water supply to be driven in a smart way. The practice of agriculture in a smart way helps to acquire knowledge of soil and temperature conditions. Developing the smart agriculture using IoT based systems not only increases the production but also avoids wastage of water. The soil moisture sensor, humidity and temperature sensor continuously monitors the soil and environmental conditions, sends the live data to smart phone via cloud service.

While raining, the moisture content may increase several times. A rain-drop detecting sensor intimates the controller if there is rainfall, making the water supply to reduce or stop depending upon the moisture content at the moment. The crop requirements such as amount of humidity, temperature and moisture content are to be studied and can be installed again in the controller to meet its circumstances. All these sensors along with NodeMCU IoT are connected to the internet and a smart phone. IoT integrates the ubiquitous communications, pervasive computing, and ambient intelligence. This will provide the basis for many new applications, such as energy monitoring, transport safety systems or building security. In an agriculture dependent country like India, it is very important to maintain a system to ensure the highest possible yield in agricultural production. This paper deals with a modern approach to centralize the agricultural system. The highlighting feature of this centralized system is to monitor and control various aspects of an agricultural system such as soil condition, irrigation management, load management, etc. wirelessly via Wi-Fi using micro controllers. It helps the user monitor and regulate work around the farm with ease and efficiency. Recently, many companies already produce the hardware equipment needed by the Internet of Things, such as sensors with communication module and control equipment with the ability to self-network. With this proposed automated centralized system, not only controlling the farm can be made easy but also it can be utilized to reduce the need for manual labor.

2. RELATED WORKS AND LITERATURE SURVEY

This paper proposes an electronic system which includes the applications of IoT. The system monitors aspects such as moisture and can control the moisture level based on a threshold value. Thus the proposed system is capable of monitoring and controlling the parameters locally. Implements an automatic irrigation IoT system based on Arduino board to modernize and improve crop productivity. The aim of the proposed paper is to increase crop productivity with less water consumption by using humidity and temperature sensors and calculating the quantity of water required for irrigation based on the sensor data, thus maximizing the crop yield. Proposes collecting data from IoT sensors and send it to the server over Wi-Fi module. The system is implemented for a poly-house. Aims to develop a product that uses low power Bluetooth and Low Power Wide Area Networks (LPWAN) communication modules for smart farming. MQ Telemetry Transport (MQTT), I2C communication method is used in monitoring and control systems, which is an IoT dedicated protocol, thereby enhancing the possibility of development of

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agricultural IoT. Implements a model to collect data from sensors to design and implement practical tasks that use different real datasets to predict values using and comparing new machine learning techniques with the standard techniques. Gives research information about decision tree algorithms in data mining for analyzing the soil dataset and predict soil fertility and thus crop production. Gives out a method for testing the soil fertility depending on the values collected by the sensors. The soil fertility once determined, is used to suggest the best suitable soil fertilizer for the crop. IoT based smart Agriculture gives information about irrigation having facilities like smart control and making intelligent decision depending upon real time data from fields. All these operations will be controlled using any smart device placed remotely and the interfacing sensors are used to perform operations along with Wi-Fi, actuators and other hardware devices. Hardware devices such as microcontrollers and microprocessors are used to create a network of interconnected devices that can wirelessly communicate with each other. The NodeMCU (Microcontroller Unit) SoC (System on Chip) development board used on the proposed system is a ESP8266 (Espressif Systems) microcontroller variant which is a cost effective Wi-Fi enabled microchip. The designed board is based on Arduino and be programmed using Arduino IDE. The reason behind using the NodeMCU is due to its extensive compatibility with the Message Queuing Telemetry Transport (MQTT) client-server protocol or I2C protocol. The MQTT protocol is lightweight, low powered connectivity protocol that enables secure connection and allows fast data transfer speeds between the NodeMCU units. This allows seamless communication between the microcontrollers as well as keeping sensitive information safe and secure. The robustness and flexibility of the platform allows this a viable option to bring the agricultural industry to the modern age in India by mainly focusing in the areas which would improve the processes involved and make the lives of farmers a lot easier.

3. PROPOSED METHOD

The Smart Agriculture Management System consists of two modules, Data Monitoring and Crop Prediction. In the data monitoring module, the sensor data is monitored using Arduino board and NodeMCU Devkit module. The sensors used are DHT-11 and Hygrometer. This data is visualized into graphs for easy understanding for the end users i.e. farmers. In the crop prediction module, the necessary crop data is collected from various sources which include lab tests of the soil sample and data collected from the sensors which are placed in the fields. User inputs this available data into the module and it predicts a suitable crop. The prediction is done using Machine learning techniques specifically the SVM classifier algorithm. The architectural diagram of the hardware components is depicted in figure 1. The Node MCU and Arduino components run on the power supply. These components are connected through Message Queuing Telemetry Transport (MQTT) protocol or I2C protocol. The sensor data thus collected through these components are displayed on the front end application.

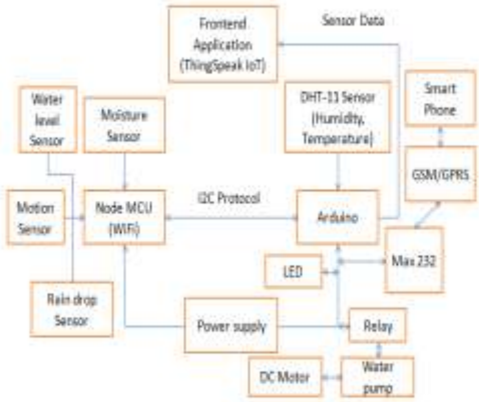

Fig. 1 Hardware design of SAMS

The architecture diagram of software components is depicted in figure 2. The application runs on the Arduino board, which houses the prediction model as well as the sensor data monitoring unit.

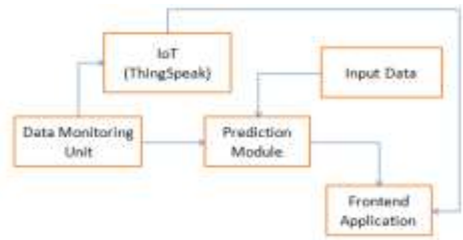

Fig. 2 Software design of SAMS

The data monitoring unit sends the sensor data to the Google Firebase and ThingSpeak IoT Cloud, which is displayed on the front end application. The prediction module collects the required data from the Firebase and outputs the results to the front end application.

The system proposed uses a microcontroller (NodeMCU) which has a Wi-Fi module (ESP8266) over it. Smartphone with ThingSpeak is used as user interface. Soil moisture sensor, humidity and temperature sensor (DHT11) and rain detection sensors along with DC motor and deek robot are used. This DC motor is connected to a water pump which pumps water to the crops when the DC motor is ON. Depending on the level of moisture, NodeMCU decides whether to water the crop or not. By using appropriate functions and conditional statements in the code written for the NodeMCU functioning, the watering of the crop starts by NodeMCU making DC motor ON when the moisture content is below a threshold value and is made OFF when there is enough moisture content in the soil. The humidity and temperature sensor gives the humidity and temperature values of the atmosphere which determine whether the crop is suitable for growth. Some crops grow only in particular weather conditions and some give better yield only for a particular temperature range. The raindrop sensor measures the intensity of rain. If there is enough rainfall to provide soil with required water, the crops are not watered. Even after raining, if the crops are not having sufficient water then water is pumped again by making DC motor ON. Data reaches the ThingSpeak cloud from NodeMCU through Wi-Fi from Wi-Fi module present on NodeMCU. From this app, the farmer can control the DC motor through various buttons and switches. When the NodeMCU gets the command from the app then the appropriate analysis is done and the DC motor is controlled. The data again travels through Wi-Fi again in the same path. The flow of the Smart farming system is as shown in the Fig. 3.

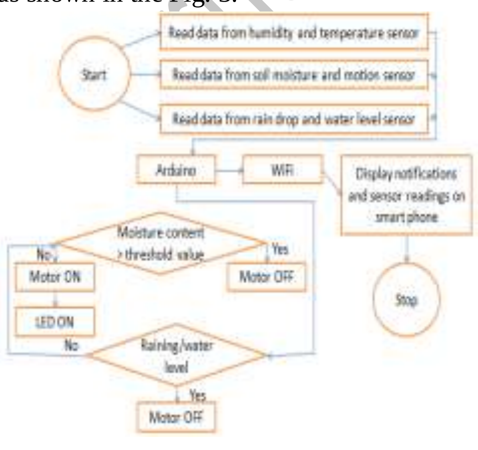

Fig. 3 Flow of smart farming system

Figure 1, 2 shows the system which is comprised of a central control/monitoring system that connects to a network of micro-controllers over the cloud. For the central control/ monitoring system, a Arduino board was used. The microcontrollers are used at the heart of the individual systems, which monitor the different sensors in the system and provide feedback to the cloud. The NodeMCU microcontroller supports MQTT or I2C IoT protocol, which allows it to access the MQTT or I2C protocol. Depending on certain conditions, some of the actions will be controlled by the Central Control System. The information on the cloud can be accessed by the user by connecting through a mobile application or a browser connected through the same Wi-Fi connection.

4. SYSTEM OVERVIEW

4.1 SOFTWARE SPECIFICATIONS

Arduino IDE is a software application that enables C program to compile and upload it to the Arduino board. It is programmed to work with different types of microcontroller. Once after compiling and uploading the code necessary action is performed. In this paper NodeMCU Devkit acts as one of the microcontroller which receives the data from the sensors. An ESP8266 JSON object is imported to achieve cross compatibility between Arduino IDE and NodeMCU framework.

ThingSpeak IoT is used for data visualization. The data sensed by the sensors is sent to the cloud with the help of microcontrollers. The Data is visualized in the form of graphs and meter gauges.

4.2 HARDWARE SPECIFICATIONS

The Raspberry Pi is a small single board PC which was created by the Raspberry Pi Foundation to impart basic computer skill sets in developing nations. Here, an Arduino board is used which has 16 Mega Hertz 64-bit quad core processor, Wi-Fi, Bluetooth and USB boot capabilities. The Arduino is used as a development board which mimics a server in the given scenario. It is equipped with a DHT 11 sensor for measuring the atmospheric temperature and humidity. This hardware is also used to run the crop prediction module.

NodeMCU is an open source IoT platform. This incorporates firmware which keeps running on ESP8266 Wi-Fi SoC from Espressif Systems. The hardware used in the development kit includes an

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ESP-12 module. NodeMCU refers to the firmware which uses Lua scripts. The board can be used very similarly to that of an Arduino. It has a flash memory in which the program logic is dumped. A moisture sensor is connected to the module which returns an analogue value. This data is used to control the motor.

A DHT 11 is a basic, and a very low cost sensor. It is used to measure the humidity and temperature of the surroundings. The unit has a capacitive humidity sensor for measuring humidity and a thermistor for measuring the temperature. The digital signal is then used to transfer the measured values onto the controller using a digital signal. The sensor has a delay of 2 seconds. This means that the sensor reading can be up to 2 seconds old.

Conductivity is used to calculate the moisture content in the soil by the sensor used. The conductivity increases when there is an increase in the moisture level and this is used to compute the level of moisture present in the soil. The sensor has both analogue and digital pins. A potentiometer is used to decide the digital truthiness of the sensor. The analogue pin gives out a value between 0 and 1023 where a value of 1023 implies low moisture content and a value of 0 implies maximum moisture level.

5. IMPLEMENTATION OF SAMS AND RESULTS

The proposed system gathers data from different sensors and feeds it to the database. DHT-11 sensor is used to compute humidity and temperature in the environment. Moisture sensor is used to measure moisture in the soil. If the moisture level goes below certain threshold value, then the motor which control the water flow to the crops. The sensor data values collected are stored in the Firebase which is later used by the crop prediction model. The sensor data is also stored in the CSV files for further use. The data is also displayed on the front end application in the form of graphs, visualized for easy understanding. Figure 4 shows the flow of data for data monitoring unit.

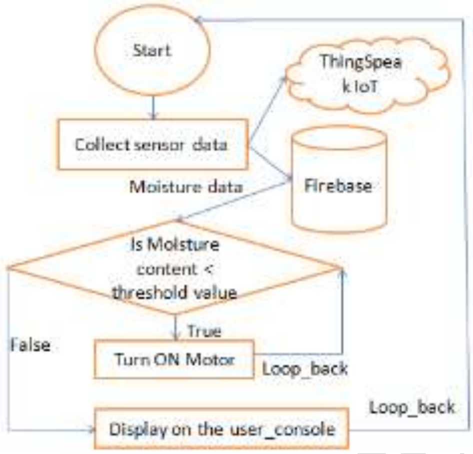

Fig. 4 Data monitoring unit of SAMS

The prediction model uses the SVM classifier to classify the data. The model uses a dataset of over 700 records of pre-processed data. The dataset is divided into train data and test data. The test data is used to validate the results. SVM classifier algorithm is used against the given input data collected from Firebase and user input, for predicting the crop. The algorithm can predict the top 3 best crops for growing along with their relative percentage of prediction. Figure 5 shows the flow of data in the crop prediction unit.

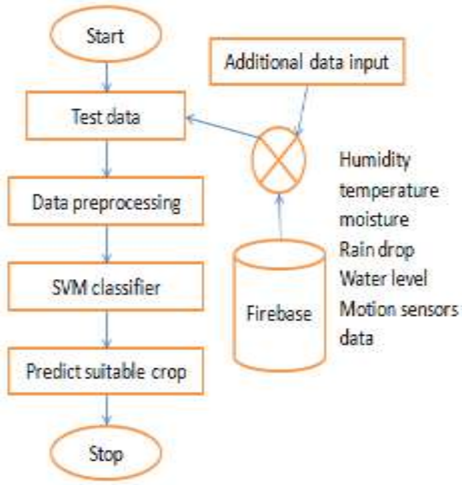

Fig. 5 Crop prediction unit of SAMS

The block diagram of proposed Smart Farming system using IoT is shown in Fig. 1 and Fig. 2. Humidity and temperature sensor (DHT11) shown in Fig. 6, consists of a thermistor, humidity sensing component and an IC. Thermistor calculates the temperature of its surrounding medium from its capability of varying its resistance due to temperature. A moisture holding substrate is placed between two electrodes in humidity sensing component. The variation in humidity produces a variation in resistance between electrodes. The variation in resistance is measured and processed by the IC which gives the humidity value to the NodeMCU. This sensor operates at a voltage range of 3.3V to 5V. The range of temperature is 0-50°C, range of humidity is 20 - 90% RH.

Fig. 6 Humidity and temperature sensor

The Soil Moisture Sensor in Fig. 7 calculates the average of dielectric permittivity along the length of the sensor. Here, dielectric permittivity is function of water. The temperature range for the working of this sensor is 10 - 30°C and voltage applied is 5V.

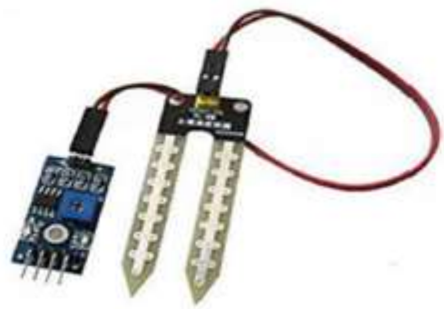

Fig. 7 Soil moisture sensor

In raindrop sensor shown in Fig. 8 as raindrops fall on the nickel lines the drop connects these lines in parallel which reduces the resistance and hence the voltage drop across the lines is also reduced. This happens because water is a good conductor of electricity. So when the voltage drop is less than a certain value it indicates that it’s raining. The range of resistance is from 100KOhm to 2MOhm.

Fig. 8 Rain drop sensor

DC Motor in Fig. 9 converts DC electrical power into mechanical power. It works on the principle of Lorentz Law. The DC motor can move in both clockwise and anticlockwise directions depending on the sign of voltage applied between its terminals. The DC motor operates at a range of 3 to 9V and runs at a speed of 3000RPM.

Fig. 9 DC Motor

NodeMCU in Fig. 10 is an open source IoT platform which includes firmware that runs on ESP8266 Wi-Fi module. Programming is done in Arduino IDE using C/C++ language or Lua script. NodeMCU has 16 GPIO pins which can be used to control other peripheral devices like sensors, LEDs, switches etc. These pins can also be used as PWM pins. It has two UART interfaces and uses XTOS operating system. It can store 4M Bytes of data. The operating voltage of NodeMCU is 5V. It uses L106 32-bit processor, and the processor's speed is 80-160MHz.

Fig. 10 NodeMCU

Deek Robot in Fig. 11 acts as an interface to the output device DC motor. It is a current amplifier and so provides enough current to drive the DC motor. Deek Robot has over temperature protection and it has internal clamp diodes. It has high noise immunity.

Fig. 11 Deek Robot

ThingSpeak is an open-source platform designed for IoT which can control hardware remotely, can display sensor data, can store data, visualize it. The components of this platform are a server which can be ran privately or use the common one, an app and libraries. Every time some information is given from the ThingSpeak app, the information travels to the ThingSpeak Cloud, from there it automatically find its way to the hardware. The connection between the cloud and the app can be through Wi-Fi, Bluetooth, GSM, Ethernet etc. The state of hardware pins can be manipulated by the commands given in the ThingSpeak app through various kinds of widgets present. Authentication token is generated after every project is created and it is a unique identifier which connects the hardware and the smart phone.

The data from Humidity and temperature sensor, raindrop sensor is sent to the digital pins of the NodeMCU. The data from Soil moisture sensor is sent to the analog pin of the NodeMCU. DC motor is connected to the NodeMCU via deek robot which is connected to two digital pins of NodeMCU. Serial monitor displays the data given by sensors if serial functions are written in the code and if serial communication between the NodeMCU and the device exists. Name of the Wi-Fi network and password are written along with the Authentication token in the code to connect the hardware to ThingSpeak app. When the code is dumped into the hardware, from then the status of the crops and soil along with the DC motor status is seen on smart phone when connected to Wi-Fi. The notifications received and the values of humidity, temperature and soil moisture, water level, motion data and GSM/GPRS notifications in smart phone and ThingSpeak for the Smart Farming system are as shown in the below figures Fig. 12, Fig. 13, Fig. 14 and Fig. 15, Fig. 16, Fig. 17, Fig. 18. The model for the Smart Farming system is as shown in the figure Fig. 19.

Fig. 12 Notification in smart phone and ThingSpeak when the DC motor is pumping water to the crops at the farm

Fig. 13 Notification in smart phone and ThingSpeak when there is rainfall at farm.

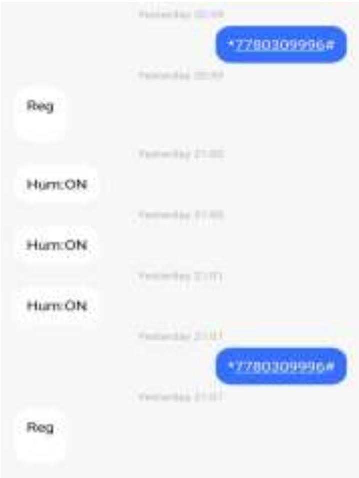

Fig. 14 Notification of all sensors data in smart phone and ThingSpeak through GSM/GPRS.

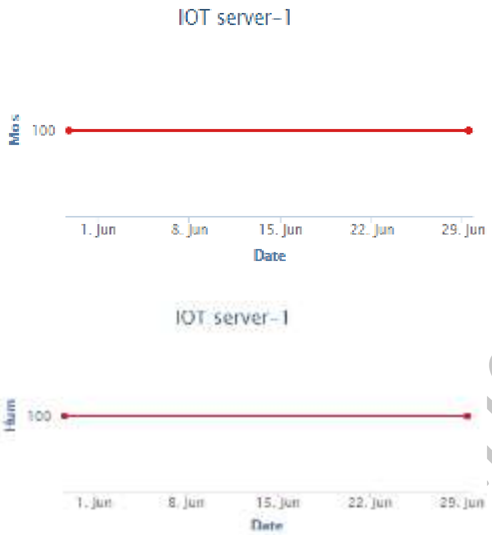

Fig. 15 Graph in ThingSpeak showing the values of humidity and moisture content in the soil of the farm

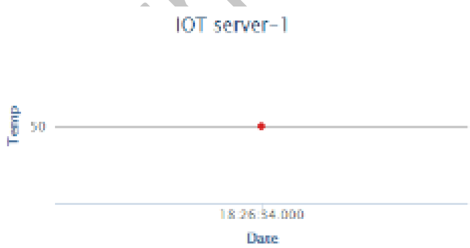

Fig. 16 Graph in ThingSpeak showing the values of temperature of the farm

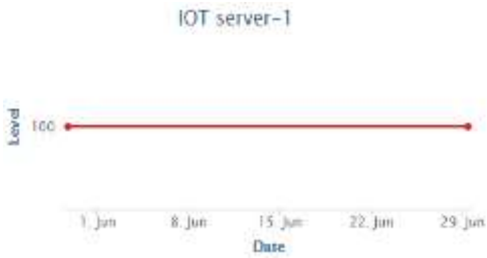

Fig. 17 Graph in ThingSpeak showing the values of water level

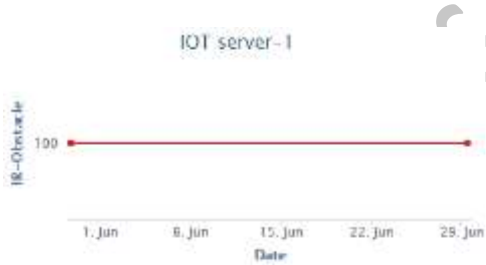

Fig. 18 Graph in ThingSpeak showing the values of Motion sensor

Fig. 19 Model of the Smart Farming system

6. CONCLUSION AND FUTURESCOPE

The paper proposes the implementation of smart agriculture management system. The automated system developed helps the end user, i.e. farmer to view and analyze the factors that are to be considered while growing a crop such as temperature, humidity and moisture. The farmer can view and understand the pattern of changing environmental variables. Accordingly, suitable crop to be grown is suggested through machine learning techniques. Thus, the system is efficient, reliable, flexible and user friendly. Although the working system is efficient enough as per requirements, some future enhancements can be done which include, monitoring of the crop health based on the features of the leaves, detection of crop disease using image processing where farmers can upload image of diseased crop and get pesticide recommendations, implement smart irrigation system to monitor weather, recommend suitable fertilizers for certain crops, collection of details of soil class, latitude, longitude to predict soil type, and thus recommend crop more efficiently.

In this paper, IoT technology is used to sense and analyze the temperature, humidity level, soil moisture level and the rain condition and DC motor is controlled using NodeMCU. All these values are sent to the smart phone using Wi-Fi. Due to the usage of this system, adequate water is pumped and rain is also utilized efficiently. This system is very much helpful to farmers as they need to regularly pump water and check the status of each crop. From anywhere in the world, farmers can know the values of humidity, temperature and soil moisture and if the DC motor is ON through the ThingSpeak app present in their smart phones. Future prospects of this work could be addition of voice-controlled interaction utilizing APIs from Amazon Alexa voice assistant. Furthermore, the access to control panel dashboard can be made secure via login authentication, so that only authorized users can access the dashboard. The prototype was also hosted locally, but it can be publicly hosted to be accessed from anywhere in the world.

Furthermore, if a farmer has multiple farms, then the farmer can add multiple farm lands under the system and interconnect them. IoT is currently a vastly untapped field with a lot of possibilities for future improvements, with the technology being only implemented commercially to small household appliances or small systems. Similar systems can be set up for large factories, industries and offices to automate parts of the system for remote surveillance and controlling. farms and more. These IoT systems will not be limited to homes, offices and cars. Cities can also work effortlessly to have transportation, traffic, waste and energy management all coordinated with IoT. Technology is progressing towards a world where everything is connected and IoT is there to achieve this.

This promise is being realized by several industries who have moved into automating and interconnecting themselves with the help of IoT. This gives the users opportunities for better data analysis and provides guidance into faster and more efficient industries. The project utilizes the features of IoT and aims at implementing this to the agricultural process of farming- with the hopes of resolving some of the issues in this area. This project also aims to minimize the labor costs and valuable investments of farmers and help the farmers save time. Though there are some limitations with the project, it is still a big leap into getting a more aspiring connected future.

Agricultural technologies are being modernized and day by day farmers are opting newer technologies and methods to cultivate crops. Similarly, the project would help the farmers to monitor and control the entire farming process which would cause an overall increase in the yield of crop production.

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