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INTERNET OF THINGS BASED SMART AGRICULTURE MONITORING SYSTEM FOR ENHANCED PRODUCTIVITY

Oborkhale, L. I., *Odo, K. O., Yerima O. and Ayanleke A. A.

Department of Electrical and Electronic Engineering, Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria.

*Corresponding Author: kayceebby@yahoo.co.uk

ABSTRACT

Internet of Things (IOT) based smart agriculture monitoring system for enhanced productivity was designed to substitute human power operation in monitoring the temperature, water supply and humidity of the crop environment to improve agricultural outputs. Tomato farm was used as the demonstration farm for the study. Internet of Things (IoT) enables various applications, like pest control, temperature sensing and soil nutrients determination. The Proteus Simulator, a model of smart farm using IoT was used for the study and the data obtained from the model was graphically analyzed using MATLAB. From the results of the designed model and the graphs, which were compared with results from a traditional tomato farm, it was observed that the IoT based smart farm increased the accuracy in temperature and humidity measurement from below 20%, that was obtained in a traditional farm, to 95%, while improving response to changes of both parameters from a number of times a day to instantaneous detection. The accuracy in measuring changes in soil moisture increased from 20% to 98% and response from 30% to 95%. The accuracy and response to detecting the presence of an intruder moved from 10% to 98%. These greatly ensure improvement in tomato production.

KEYWORDS: Internet, Monitoring system, Smart agriculture, Crop environment, Productivity.

1. INTRODUCTION

Agriculture apart from being a source of livelihood for people all around the world, it has particularly been one of the primary occupations in Nigeria for ages, and before Petroleum was discovered, it was the leading source of income for the Nigerian government, providing employment for about 30% of the Nigerian population as of 2010 and contributed 32% to Gross Domestic Product (GDP) in 2001 (Yakubu and Akanegbu, 2015). But now due to migration of people from rural to urban areas, and due to the believe by many that agriculture is stressful even with the use of machineries and many other factors, there has been hindrance in the development of agriculture. It then becomes very essential to make effective intervention in agriculture and a solution to this problem is Smart Agriculture. This is achieved by installing electronic equipment in a farm that collect and analyze data from the farm and send it through wireless protocol to the farmer. The collected data provide information about the various environmental factors. However, monitoring the environmental factor sis not the complete solution to increase the yield of crops. There are other factors that decrease the productivity largely. Hence, automation must be implemented in agriculture to overcome these problems (Suma, *et al*, 2017). In order to provide solution to all such problems, it is necessary to develop an integrated system, which will take care of all factors affecting the productivity in every stage. According to Martin (2017), the Internet of Things (IoT) is the network of physical devices, vehicles, home appliances and other items embedded with electronics, software, sensors, actuators, and connectivity which enable these objects to connect and exchange data. Each thing is uniquely recognizable via its embedded computing system with exceptional identifiers and the capacity to move information over a system without expecting human-to-human or human-to-PC communication. IoT integration with Wireless sensor networks has potentials to change the way of development in agriculture and give more contributions to smart agriculture (Patil and Kale, 2016). Internet of Things (IoT) involves a three-tier system. It includes perception layer, network layer and application layer. Perception layer includes sensor motes. Information Communication Technology (ICT) enabled devices, like sensor motes are building blocks of sensor technology. It includes cameras, Radio-Frequency Identification (RFID) tags, sensors and sensor network used to recognize objects and collecting real time information. The network layer is an infrastructure of the IoT to realize universal service. It combines the perception layer and application layer. The latter is a layer that combines the IOT with the technology of specific industry. IoT is applied in all areas of industry, including smart agriculture, engineering, smart parking, smart building environmental monitoring, healthcare, transportation and many more. Agriculture is a vital area which targets millions of people (Patil and Kale, 2016).

Agriculture monitoring is a farming management dependent on monitoring, estimating and responding to inter and intra-field and variability in crops. The goal of agriculture monitoring research is to design a precision system for entire farm monitoring and the management with the objective of improving returns on inputs while preserving resources. An agricultural environment-monitoring framework gives environmental monitoring services and facility controlling services, and in this manner keeps up any sort of plants developing condition in an ideal status. This framework likewise can improve the comfort and efficiency of users in plantation sector (Hwang *et al*., 2010).

1.1 Literature Review

Kaushik *et al* (2020) researched on smart agriculture management system using Internet of Things. In their work, an IoT in an agriculture framework includes various benefits in managing and monitoring the crops. An architectural framework was developed which integrated the internet of things (IoT) with the production of crops, different measures and methods were used to monitor crops using cloud computing. The approach provided real-time analysis of data collected from sensors placed in crops and produced result to farmer which is necessary for the monitoring the crop growth which reduces the time, energy of the farmer.

Sushant researched on Internet-of-Things (IoT) based smart agriculture. In his work, IoT allows the farmers to remotely access his field and act as per the need of the hour without his actual presence on the field, reduces human effort, saves time, and helps in precise agricultural practices. IoT adaptation can reduce the cost and increase the productivity of the crops. However, the study was based on the review on carrying out the need, utilization, applications, advantages, current and future trends of IoT in agriculture.

Syeda *et al* (2020) presented the overview of agriculture monitoring by means IoT based systems. They said that farmers are facing the situation where the effects of atmospheric conditions are severe on the crop. On the other hand, the improper planning of the type of crop to be cultivated may lead to the low returns from market. The Smart systems for monitoring the crop and soil help the farmer to enhance the cultivation. The IoT based system can be implemented to monitor the crop and soil in order to control the use of resources depending upon the requirement. However, their research did not implement the use of IoT in monitoring the crop for enhanced productivity.

In the work of Rehman *et al* (2022) titled a revisit of Internet of Things technologies for monitoring and control strategies in smart agriculture. The authors said that with the rise of new technologies, such as the Internet of Things, raising the productivity of agricultural and farming activities is critical to improving yields and cost-effectiveness. The paper demonstrated IoT applications, benefits, current obstacles, and potential solutions in smart agriculture. This smart agricultural system aimed to find existing techniques that may be used to boost crop yield and save time, such as water, pesticides, irrigation, crop, and fertilizer management but did not implement the use of IoT in monitoring the crop for enhanced productivity. Researchers have given various approaches to the concept of smart agriculture monitoring and we have seen their limitations. In order to obtain a highly efficient smart agriculture monitoring system, we have carried out a research work to design and simulate Internet of Things (IoT) based technology in monitoring a crop plantation for improved productivity. The improvement includes making the IoT based smart agriculture monitoring system variable instead of fixed. This is important, as it will make it possible to change sensors' threshold value to suit the crop to be planted or region of plantation and modeling the system such that monitoring, and control commands can be sent over a GSM Network using SMS technology.

2. MATERIALS AND METHOD

2.1 Materials

The IoT system and equipment employed in the study includes; A PIC16F877A Microcontroller, a temperature sensor, a soil moisture sensor, a humidity sensor and a PIR sensor. The equipment type selection was done considering the fact that the model will only be simulated in software; there will be no hardware/real-life implementation.

2.2 Research design

The IoT based monitoring system design as in this research is in 3 sections, i.e. The Data Acquisition or field section, the Data Control section and the User Interface section. In the field section, various sensors are deployed in the field depending on the parameters of interest. In a Tomato plantation, which is the case study for this project, climatic factors like air temperature, humidity, soil temperature and soil moisture, determine growth rate; so, we deploy sensors like temperature sensor, moisture sensor and, humidity sensor etc. The data collected from these sensors are connected to a microcontroller through a RS232 interface.

In the control section, the received data is verified with the pre-set threshold value. If the data exceeds the threshold value, a buzzer will be switched ON and an LED starts to blink. Then an alarm of the occurrence is sent as a message to the farmer. The user interface can be a webpage, mobile application or short message service (SMS) system via a mobile phone, which can be used to communicate and interact with the equipment in the field section. In this project, we employ the use of short message service, which apart from being used to monitor the farm can be developed such that it can be used to send operational signal to equipment in the field, some of which include opening irrigation gate so as to water the farm. Figure 1 shows the block diagram representation of the design. The sensors detect the parameters and convert the detected data into electric signals, which is in turn worked on by the controller, by comparing it to already set threshold values. A display is also connected to the controller. This is to display the results from the controller. Depending on the result from the controller, an instruction is sent to a relay to fix the problem with the system while also informing the farmer via an SMS message.

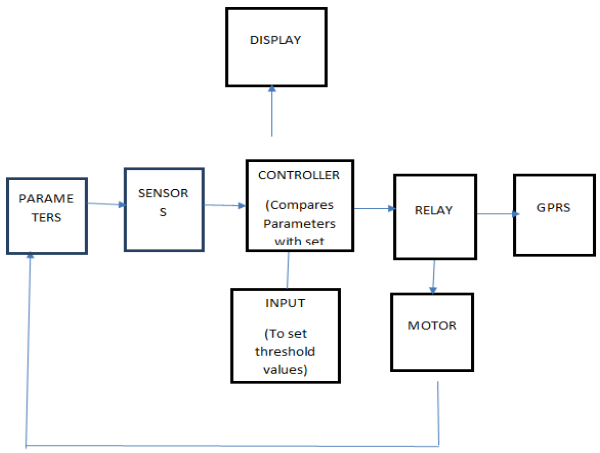

Figure 1: Block Diagram of the IoT Based Smart Agriculture System

2.3 System Design

The diagram (figure 2) shows a description of the design architecture for the proposed IoT based monitoring system. The system is composed of IoT equipment that includes; A Microcontroller (PIC16F877A), GSM/GPRS Module, LM35 Temperature Sensor, Soil Moisture Sensor, Humidity Sensor etc. The research was carried out using Proteus Simulator.

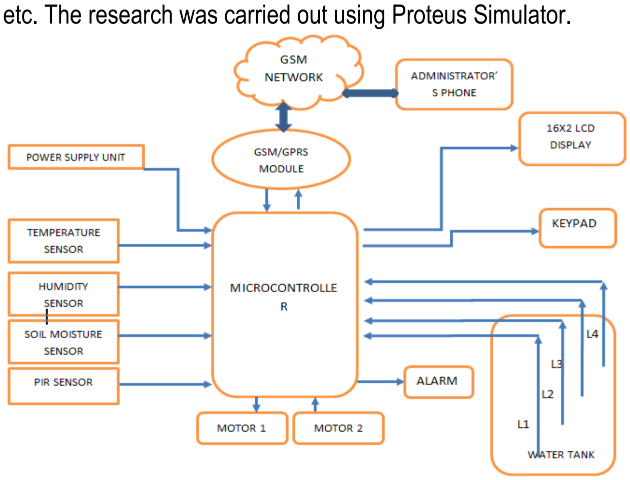

Figure 2: Design Architecture for the IoT Based Smart Agriculture System

2.4 System Configuration and Operation

The system design is such that once powered ON; the installed LCD will come on then request that the user input the upper and lower limit for Water level sensor, Temperature Sensor, Soil Moisture Sensor, PIR sensor and Humidity Sensor readings, which will be inputted by user using the Keypad. Once this is done, the sensors become active and upload readings to the Microcontroller, and these readings are displayed on the LCD one after the other.

Incorporated also to the design are 2 motors, one of which is representing a water pumping machine for pumping water to the water storage tank and the other represents another pumping machine which purpose is to sprinkle water on the farm by drawing water from the storage tank to a series of pipe run around the farm with holes in them for sprinkling water.

3 RESULTS AND DISCUSSION

3.1. Temperature sensor

The required temperature for tomatoes varies with the time of the day and the developmental stage of the plant, but it is agreed that for optimal yield the required temperature range should be between 16°C and 26°C (Redmond *et al*., 2018). It is worthy to note that the simulation is designed to cover temperatures ranging from 0°C to 100°C (figure 3).

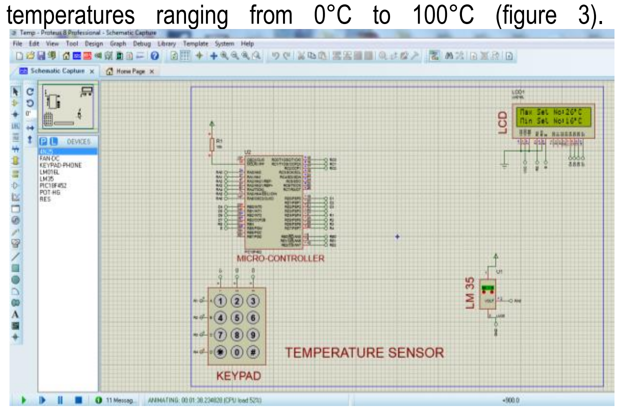

Fig 3: Temperature Sensor displaying set values

The temperature sensor range set was 16°C to 26°C (Table 1), when the temperature was read as 15°C the result displayed on the LCD screen was "Too Low", when the temperature was at 20°C, the result was "Ok", and when the temperature was at 28°C, the displayed result was "Too High".

Table 1: Temperature Sensor

Temperature	Status
15°C	Too Low
20°C	Ok
28°C	Too High

Set values: Min= 16°C Max= 26°C

3.2 Humidity sensor

The ideal humidity level for tomato plants should be between 65% to 75% during the night and 80% to 90% during the day (Buschermohle and Grandle, 2017). For the purpose of demonstration, the humidity level used is between 70% and

85%. Though the simulation was designed for any level ranging from 0% to 100% (figure 4).

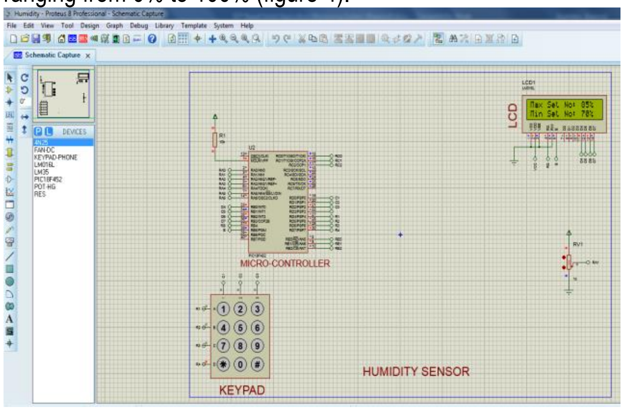

Figure 4: Humidity Sensor displaying set values

The humidity level was set to range from 70% to 85%, when the humidity was at 66% the result displayed on the LCD screen was "Too Low", when the humidity increased to 78%, the result was "Ok", and when the humidity got as high as 86%, the displayed result was "Too High". Table 2 shows the result of humidity sensor.

Table 2: Result of Humidity Sensor

Humidity	Status
66%	Too Low
78%	Ok
86%	Too High

Set values: Min= 70% Max= 85%

3.3 Soil moisture sensor

Tomato plants need an even soil moisture for optimal growth. The soil is expected to remain damp always. However, the water content should not be too much in order not to flood the plants. For the purpose of demonstration, the level of water in the soil was set to 60% to 75%. The range provided by the simulation, however covers from 0% to 100% to make room for flexibility (figure 5).

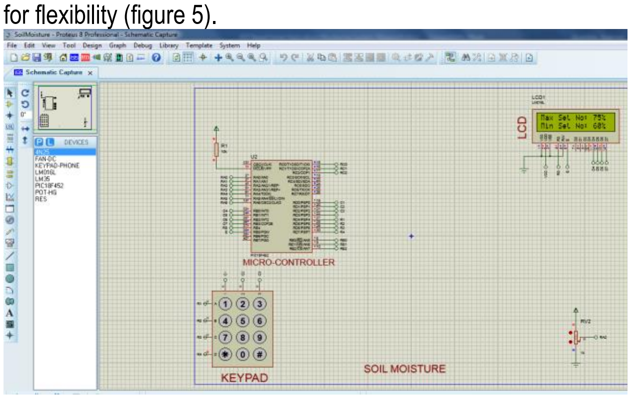

Figure 5: Soil Moisture Sensor displaying set values

The Soil Moisture level was set to range from 60% to 75%, when the soil moisture dropped to 55% the result displayed on the LCD screen was "Too Low", when it increases to 65%, the result was "Ok", and when the humidity got to 78%, the displayed result was "Too High". Table 3 shows the result of soil moisture sensor.

Table 3: Soil Moisture Sensor Result

Soil Moisture	Status
55%	Too Low
65%	Ok
78%	Too High

Set values: Min = 60% Max = 75%

3.4 Water level sensor

The water level sensor is to check the level of water in that tank that supplies water to the farm. The level can be set for to any level ranging from 0% to 100%, but for the purpose of demonstration, it is set to 15% (figure 6).

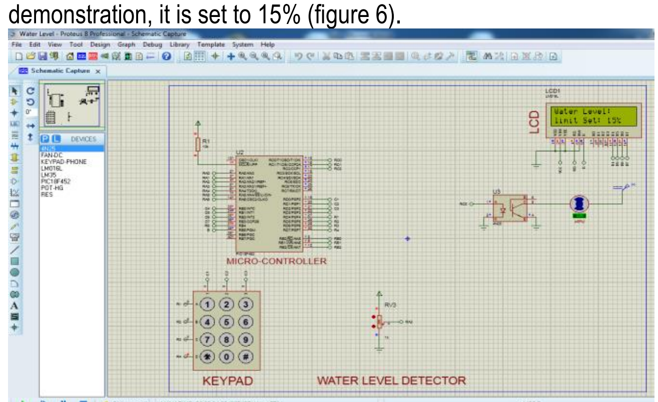

Figure 6: Water Level Detector displaying set value

The water level was set at 15% in order not to make the tank completely empty before an action is taken. When the water level is at a level higher than 15%, the status is reported as "Ok". As soon as the water level drops below 15% as demonstrated in Fig 4.15, the status changes to "Low" and the motor comes on in order to pump water into the tank. Table 4 shows the result of water level sensor.

Table 4: Water Level Sensor Results

Water Level	Status
14%	Low
35%	Ok

Set value: Limit = 15%

3.5 Motion detection sensor

In order to detect intruders, the motion detection senses the changes in the radiant heat levels emitted by surrounding objects, if the heat level changes beyond its threshold value, the motion detector is triggered (figure 7). The motion detector changes status to “Motion Detected” and triggers an alarm whenever an intruder comes close enough to alter the radiant heat of the environment.

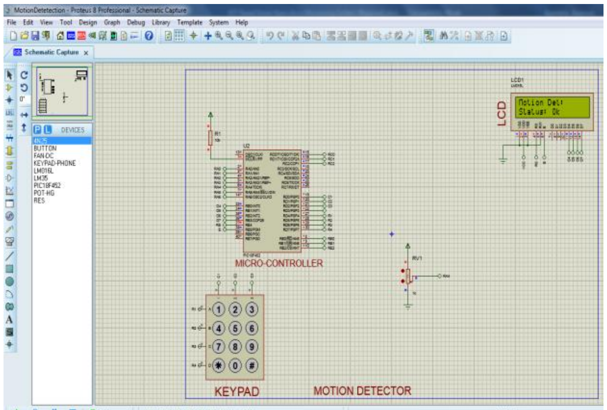

Figure 7: Motion Detector displaying status as “Ok”

All the results of the readings are shown on the LCD screen one after the other, with the Water Level coming first, then the Temperature, the Soil Moisture, the Humidity, and lastly the Moisture Detector. For every reading, their set values are first displayed, then followed by the current reading of the parameters. Each display has a time lag of 5 seconds before the screen moves to display the next reading (figure 8).

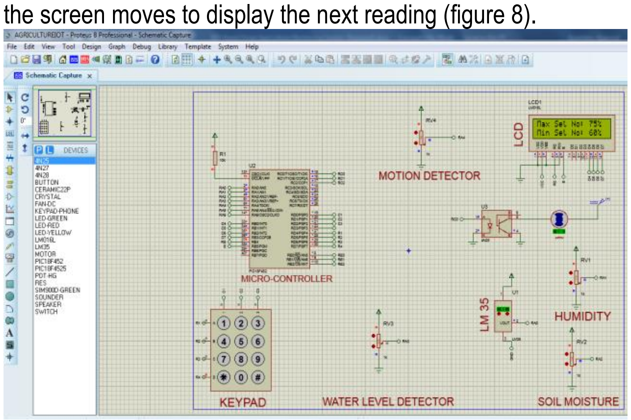

Figure 8: The IOT Simulation as a whole showing integrated sensors

3.6 MATLAB/Simulink

The output of each sensor over a 24-hour period was fed into a Simulink signal builder in order to observe the changes in the parameters that are being measured. The figures below showed the simulation on Simulink and the resultant graphs.

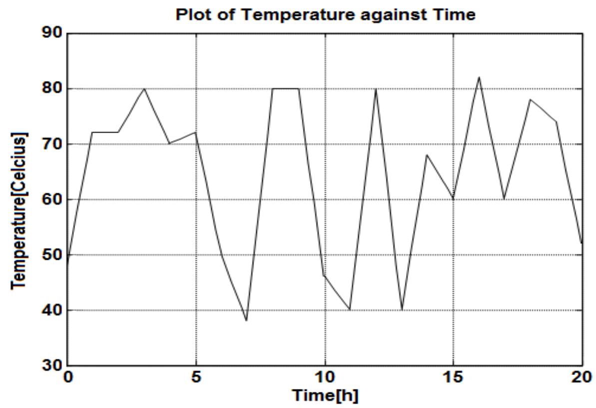

Figure 9: Plot of temperature against time

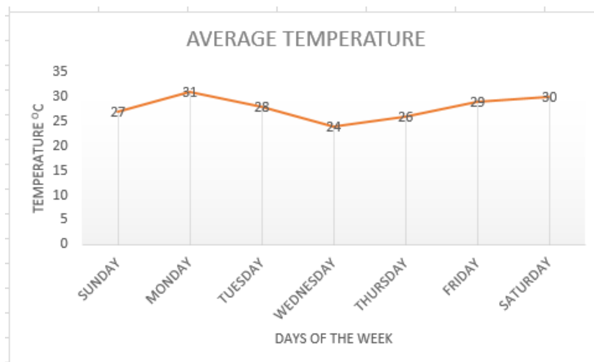

Figure 10: Plot of temperature against time gotten from traditional tomato farm

Comparison of the two graphs:

Figure 10 is a graph gotten from a tomato farm where the traditional way of measuring and monitoring temperature was used. The farmer measured the temperature at different times in the day and an average was recorded for each day, after which the result for a week of monitoring was plotted in a graph, (Maria *et al*, 2020). When compared with the results gotten from the IoT based farm which responded to every change in temperature instantaneously, it was found that response was increased from 3 times a day (periods that samples were taken) to the exact instant a change is detected, this helped in increasing the accuracy from below 20% to 95 %.

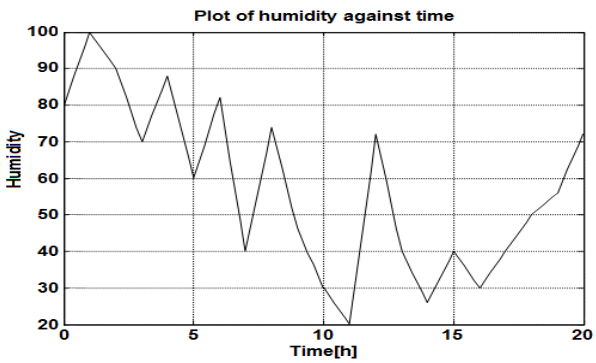

Figure 11: Plot of humidity against time

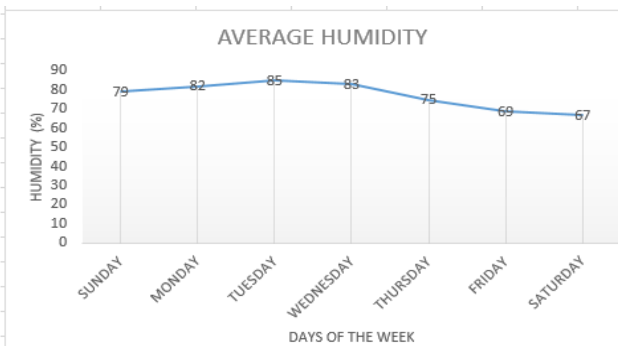

Figure 12: Plot of humidity against time gotten from traditional tomato farm

Figure 12 is a graph gotten from a tomato farm where the farmer measured the humidity at different times in the day and an average was taken for each day, after which result of a week of monitoring was plotted in a graph, (Maria *et al*, 2020). When compared with the results gotten from the IoT based farm (figure 12) which responded to every change in humidity instantaneously, it was found that response was increased from 3 times a day (periods that samples were taken) to the exact instant a change is detected, this helped in increasing the accuracy from below 20% to 95 %.

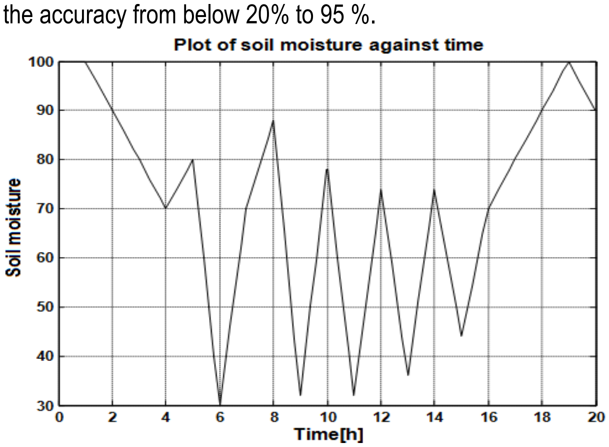

Figure 13: Plot of Soil moisture against time.

Traditionally, soil moisture is measured through the feel and appearance method. This involves collecting soil samples from different locations and depths on the field, made into balls, and squeezed to feel the cohesiveness of the soil. This method is quite inaccurate and there was no way to effectively measure the changes in soil moisture instantaneously. The IoT smart does not only effectively measure the changes in soil moisture instantaneously as shown in the graph in figure 13, it also triggers a series of response to remedy the situation by watering the field. Because the farmer does not have to be manually water the field the moment the farm lacks the required moisture, accuracy was increased from about 20% to 98% and response from about 30% to 95%

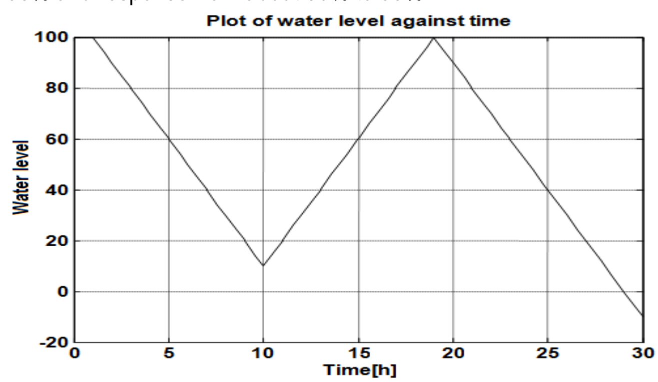

Figure 14: Plot of water level against time

Figure 14 simple shows the behaviour of the water in storage tank. The system was designed to pump water into the tank on its own whenever the water falls below the set value. This will greatly reduce the need for manpower and save time.

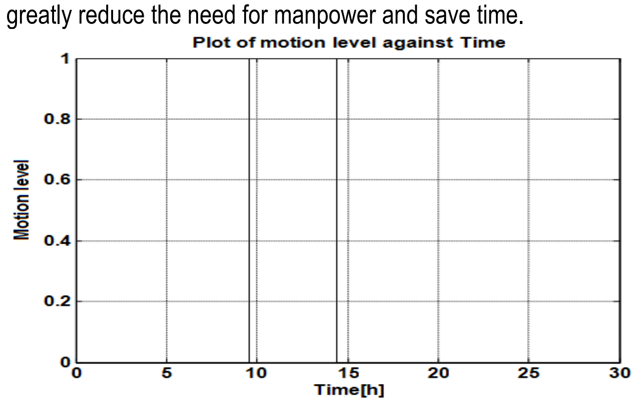

Figure 15: Plot of motion level against time

The most common way of scaring off intruders and pests is using scarecrow. This method obviously cannot work with humans and some pests. As shown by figure 15, the IoT smart farm detects an intruder immediately there is an intrusion. This has helped to increased accuracy and response below 10% to 98%.

From the graphs in figures 9, 11, 14, 15 and 16, it can be seen that the behaviours of temperature, soil moisture and humidity are similar. These three parameters are not in the control of the farmer, they are majorly controlled by nature and are not always linear and/or static for long, hence the sinusoidal nature of their graphs.

The graph for the water level can be seen to fall linearly, and then rise linearly. This clearly showed the behaviour of the water in the tank. The linear slope downwards represented the steady fall in water level, when the water level dropped below the set value (in this case 15%), the water pump turned up automatically to pump water into the tank and consequently there would be a steady rise in the water level as represented by the upward slope.

The graph from the motion detector is a step function. This is because the sensor only records two states; zero (0) when no motion is detected and one (1) when motion is detected.

4. CONCLUSION

This research work designed and simulated a smart agriculture monitoring system using internet of things. Internet of Things has proved to be useful in communication between devices and gathering of data. The agriculture monitoring system serves as a reliable and efficient system that also gives room for corrective actions to be taken. Smart monitoring of parameters reduces the man activity while it allows the farmer to observe real-time and with precision, the events on the farm. It consumes less power and provides a low cost and effective wireless sensor network technique to acquire the soil moisture, humudity and temperature from various location of farm. The system is more efficient and beneficial for farmers. It gives the information about the temperature, humidity, soil water level, water supply, and intrusion by pest or humans in the farm with the help of sensor nodes and other components communicating with one another. The system can be used in green house and temperature dependent plants. Though tomato was used in the demonstration, the system is flexible and can be used for a wide variety of plants. It is a comprehensive system designed to close the gap between farmers and technology in agriculture. The implemented framework will be helpful to the farmers to understand the requirements to grow crops in critical seasons in a better manner in order to mitigate loss. Surely, the application of such a system in the field can definitely help to improve yield of the crops and increase overall production

The IoT technology does not only effectively measure the changes in soil moisture instantaneously; it also triggers a series of response to remedy the situation by watering the field.

Results revealed that the behaviours of temperature, soil moisture and humidity are similar. These three parameters are not in the control of the farmer, they are majorly controlled by nature and are not always linear and/or static for long, hence the sinusoidal nature of their graphs. These results obtained are much more preferable because the IoT based smart agriculture monitoring system was made to be varying instead of fixed which is suitable for change in sensor's threshold value to suit the crop to be planted or region of plantation. Also, the design was targeted on one specific application and modeling the system such that monitoring, and control commands can be sent over a GSM Network using SMS technology. This is much better as mobile phones are usually with their users and convenient to use, as compared to having to log on to a personal computer (PC) and connecting to a data network; which will be relatively slow and less available.

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