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Precision Agriculture Monitoring System using Internet of Things (IoT)

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Abstract: There are many agriculture applications incorporating IoT to increase the productivity of the crops, however, these applications are still facing many challenges. The researchers are working to defeat these challenges in the futuristic applications by deploying new technologies; these technologies are not easy to be used by farmers. So, this research work aims to build a real-time, cost-effective Precision Agriculture Monitoring System with a user-friendly interface to help the farmers monitor their farm parameter's variation (weather, water, soil, pest detection, intrusion detection, fire detection) periodically from anywhere and at any time using their smart-phones. The proposed system will act as a decision support system helps farmers to take the appropriate actions based on the farm parameter's variation; by sending an alert email to the farmer when it is required.

Keywords: Beagle Bone Black Rev C, Sensors, Ethernet, Web Application, smart-phone

I. INTRODUCTION

Precision Agriculture (PA) as explained in [1], it is one of the promising technologies to increase the crop productivity without affecting the product quality. There are many technologies applied in the agricultural domain using (Internet of Things) IoT to increase the productivity and overcome the existing challenges, which are; first, increase food production is required to satisfy growing population and prevent from the starvation era. Second, the lack in the numbers of labours as a result of civilization adding an extra challenge into agriculture sector, so to overcome this challenge require deploying automation agriculture systems required neither time and efforts nor human intervention. Third, as a result of climate change and degradation of water resources lead deploying some technologies to help to manage the farm water resources precisely. Fourth, reduce chemicals impact on human health is also required, by spraying these chemicals regarding of (pesticide or fertilizer) based on the crop needs instead of scheduled traditional methods. In addition to all that all the existing precision agriculture monitoring systems are very costly compared to farmer's profits, also the need for real-time systems to keep on monitoring all the farm parameters variations is also required; along with a user-friendly interface enable the farmers to monitor their farms from anywhere and at any time. Uses of IoT technologies in agriculture envision improving productivity and sustainability.

Precision Agriculture from [2] makes use of a range of technologies that include GPS Services, sensors, and big data to optimize crop yields. This enables better decision to be created, leading to reduce the waste of resources and maximize the efficiency of operations.

Currently, the agriculture domain needs to evolve new technologies alongside with disciplines and skills include monitoring systems, robotics, GPS technology, computer-based imaging, environmental controls, and solutions for weather forecasting, technological solutions, and more. These technologies are not easy to be used by farmers, so this research work aims to implement user-friendly interface easy to use by farmers and doesn't required any training to use it.

II. LITERATURE REVIEW

IoT becomes a global concept, defined by ITU-T, Auto-ID labs, and IERC, but semantically IoT is defined "a worldwide network of interconnected objects uniquely addressable, based on standard communication protocols." [4]. The research papers discussed the existing challenges, also defined the agriculture framework and the supported IoT hardware platforms and used wireless communications technologies in addition to existing cloud solutions, moreover gives an overview of all WSN crop monitoring systems, its working principle, components, advantages, and the limitations along with some case studies ([5], [6]).

IoT empower the crops irrigating based on its needs using soil moisture sensor to read the percentage of the moisture in the sensor periodically and based on that then the irrigation will be decided if needed they will turn on the pump unless waiting for next reading in the next period. IoT agriculture supporting techniques help farmers and make them connected to their farms anywhere and anytime based on WSN using their Smart-phones.

Smart farming technologies, Agri-IoT have an impacting role in facilitating decision-making by farmers [8], introduces an open standard and semantics framework based on IoT enabled smart farming applications in medium to large farms. This research has been supported by the P-SPHERE project, which has received funding from the European Union's Horizon 2020 research and innovation program. There are many proposed schemes try to overcome the challenge of creating multi-purpose hierarchical network composed of smart nodes able to gain and manage heterogeneous data and spaces according to the Internet of Things paradigm as it's explained in [9].

Also, there are automated irrigation and fire alert system based on Hargreaves equation using weather forecast and ZigBee Protocol along with GSM protocol [10]. The challenge of energy availability and the price is still one of the greatest challenges in farm areas, so design a WSN using low cost and low energy efficient framework, using Eco-friendly and energy efficient Sensor technology for precision agriculture irrigation is required to achieve sustainability ([11], [12]).

III.PROPOSED SYSTEM

There are many existing PA monitoring systems, but the majority of those systems they are focusing on monitor the irrigation process not other parameters variation of the farm, however, there are many of the farm parameters change periodically and also required to be monitored periodically to help farmers take the appropriate action when needed, and this type of monitoring systems will moreover help farmers to manage their farm resources effectively. So this research work aims to prototype real-time, cost-effective precision agricultural monitoring system using the Internet of Things principles with user-friendly interface and less power consumption by using inexpensive, low power hardware components with high accuracy [9].

A. *Proposed System Work Flow*

The design can be divided into five levels, as shown in Fig. 1

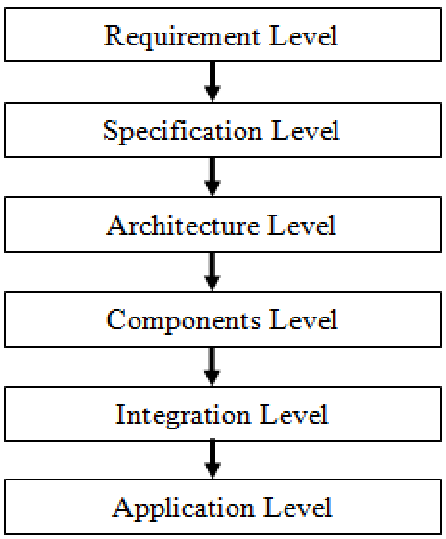

Fig. 1 Proposed System design sequence

The first level of proposed system design; *Requirement level* can be divided into two categories: 1) Functional Requirements, which is including technical details about collecting, processing and storing the field sensing data which will use different sensors to detect soil moisture, temperature and humidity, rain detection, smoke detection, and motion detection sensing. 2) Non-Functional Requirements, which is mutually exclusive on the functional requirements, the proposed system aim to monitor the soil, water, weather, crops pests, fire and intrusion detection. The proposed system will act as decision support platform to help farmers controlling their farm resources precisely by sending an alert if one of these parameters exceeding the predefined threshold.

The second design level is *Specification level*; this level will give a detailed assessment of the required devices which it will be summarized in Table 1.

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Table 1 list all the hardware requirements

Sr. No.	Devices	Specifications
1	Sensors	DHT22, 2 PIR with different sizes, MQ-2, raindrop sensor, YL-38+YL-69, Colour detection sensor(TCS230), water level sensor
2	BeagleBone Black	IoT supported platform, based on Sitara AM3358BZCZ100 processor with powerful specifications and consume less energy compared to other IoT supported platforms; require only 3.3 V, 210 – 460 mA
3	PC	Connect to BBB to connected into a Web-Server which will host the web application using Cloud9IDE
4	Smart-Phone	Enable farmer to connect to web-application to monitor his farm remotely
5	Buzzer	For alarm in case of fire or intrusion

The Third level of design sequence is *Component level*; which is responsible for performing the functions in architecture, it is important to level of the design which consists of hardware components and software components as discussed below: Hardware Components: It is the physical devices (which are outlined in table 5.1) that are a part of the system, which connects the other components, provides input and output to and from the application. Software Components: Which including the interfacing between hardware and PC, for BBB Debian 9.2 have been installed, release image for BeagleBone black because it is the last version it is released in October 2017. Cloud9IDE (which is embedded with BBB images) also will be used for programming, editing and debugging python codes of the system. To interfacing sensors with BBB, it required some packages required to be installed as it will be discussed later in section IV.

The fourth level of design is *Integration level*; in this design level, all the components will be connected together to form the required architecture, the connections between components to make the system work properly as its intended specifications as is shown in Fig. 2.

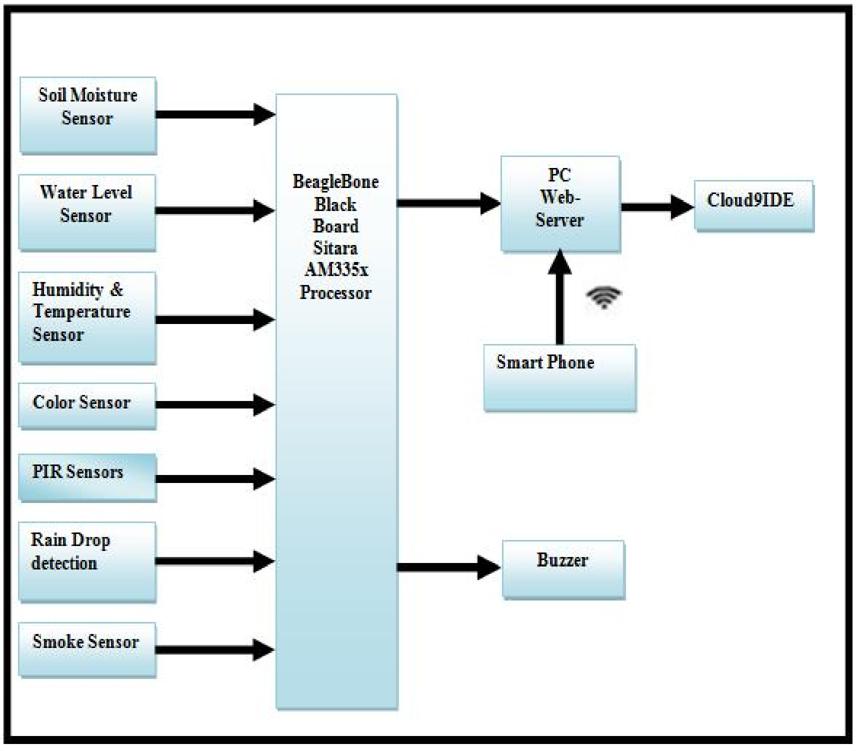

Fig. 2 Proposed System Block diagram

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The fifth and last level is the *Application level*; in this level, the web app will be designed to enable farmers to monitor their farm via their smart-phone remotely with less effort. The WEB APP also will act as a decision support system.
So the proposed system will monitor six of the farm parameters which their variations affect the farm resources, tasks, and productivity, these parameters include monitoring (weather, water, soil, crop pests, in addition to fire detection and intrusion detection), therefore the system will consist of three modules as it will be explained in section IV.

IV. PROPOSED SYSTEM MODULES INTEGRATION AND RESULTS

The proposed system consist of three modules, in all three modules BeagleBone Black Rev. C (BBB) will be connected to the Internet via Ethernet connection as it will explain in the following sections

A. Fire Detection Monitoring Module

This module based on (BBB), an MQ-2 Smoke Sensor and a buzzer as an alarm, the working principle is shown in Fig. 3, MQ-2 sensor has a built-in potentiometer to adjust sensitivity based on the accuracy of the gas detection. The MQ-2 sensor, and Buzzer will be interfaced with BBB as shown in Fig. 4, This module will check the output of MQ-2 sensor periodically, if MQ-2 detected fire in your farm, the DO-LED of the MQ2 sensor will be switch ON, also an alert email fire detection in your farm will be sent to the farmer to take the proper action, also the buzzer will be switch ON to warn the farmer, otherwise, everything will be fine.

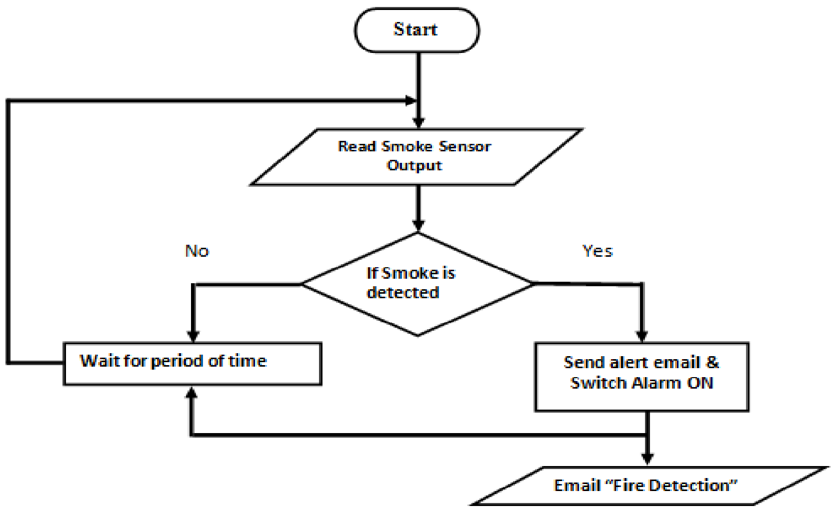

Fig. 3 Fire Detection algorithm

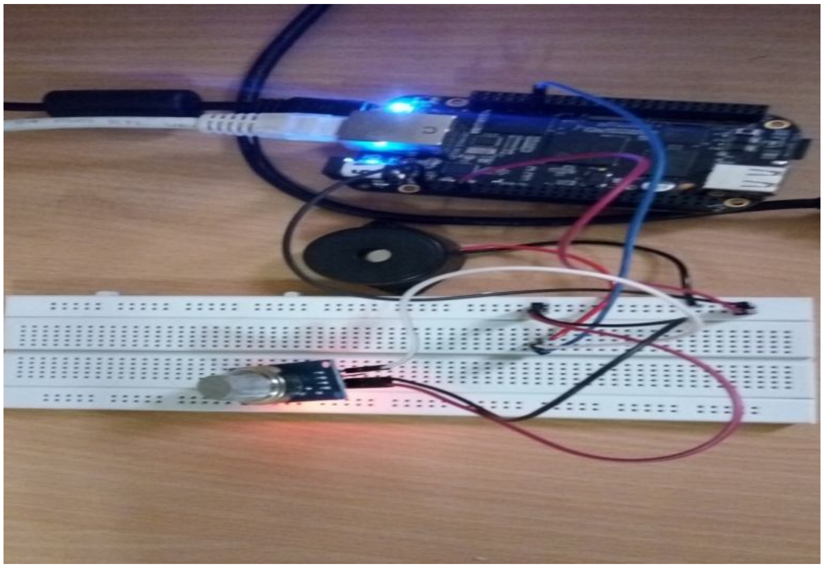

Fig. 4 Fire detection monitoring module

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When the script run from Cloud9 IDE of BBB the output is shown in Fig. 5:

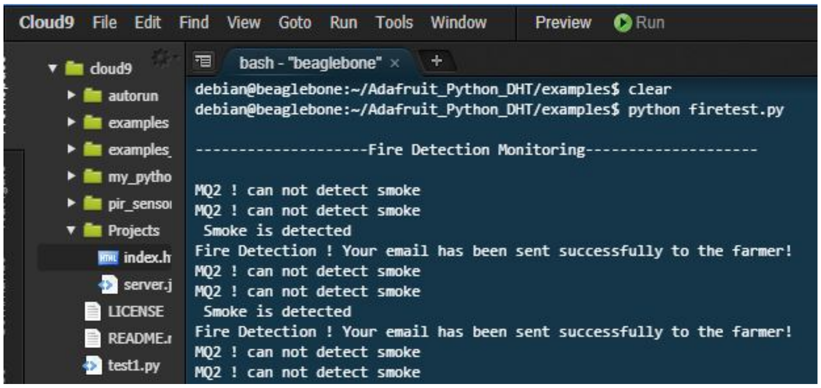

Fig. 5 fire detection monitoring module output

B. Intrusion Detection and Pests Detection Monitoring Module

This module is based on BBB, two PIR sensors with different lens sizes the integration is shown in Fig.6.

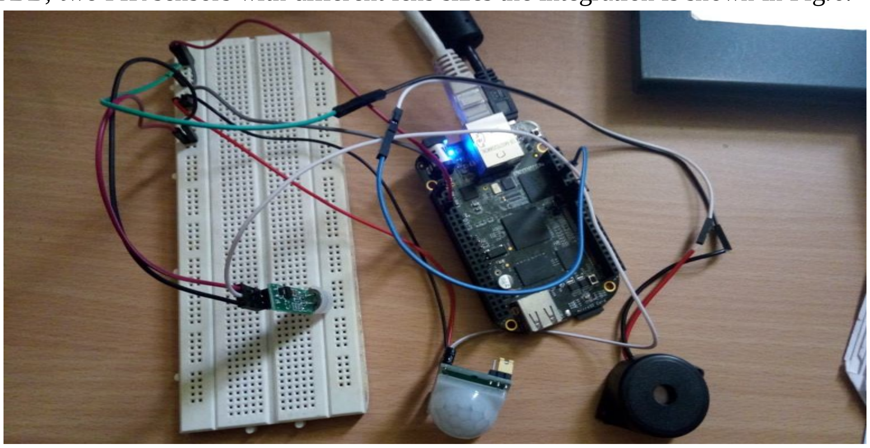

Fig. 6 Intrusion detection and pest's detection module

The working of the algorithm principle of the monitoring module is summarized in Fig. 7.

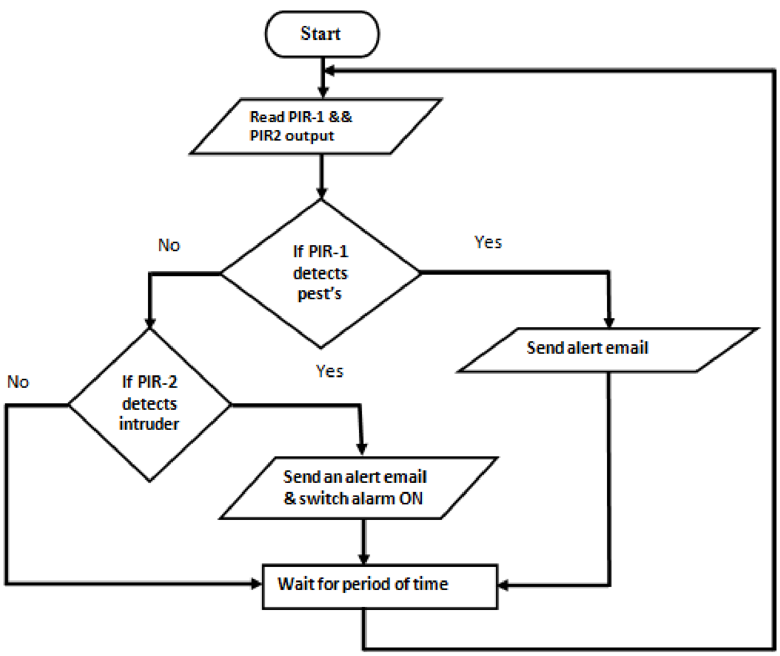

Fig. 7 Pests' detection and ID monitoring flowchart

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1) *Intrusion Detection (ID):* is based on interfacing BBB with Passive Infrared (PIR) Sensor, which detects the moving objects based on the radiated heat from its bodies it less power consumption sensor with a bit large lens size, this sensor has two adjustable potentiometers for a range of detection and time. An alert email will be sent to the farmer in case of an intrusion detected by the PIR sensors. The Buzzer will also be interfaced with BBB and coded to be switch ON in case of intrusion detection; it will also scare the intruder whatever the intruder is a thief or an animal. By run the script for ID from Cloud9IDE of BBB, the output is shown in Fig. 8:

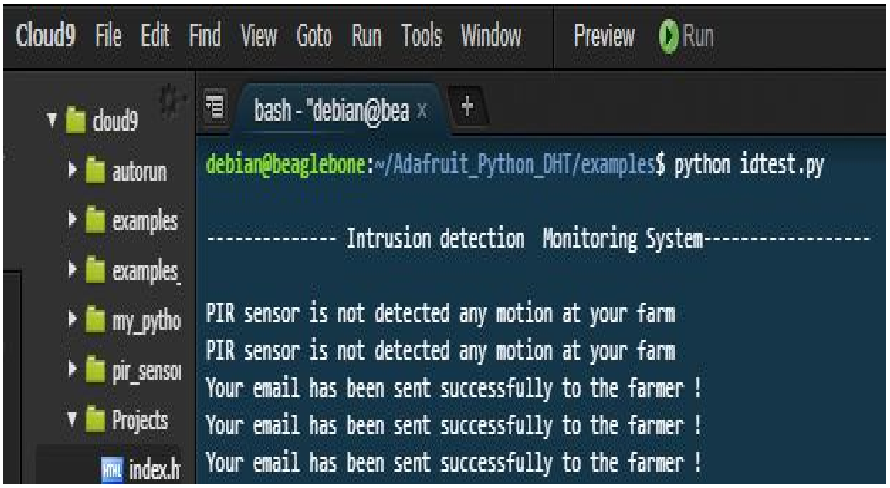

Fig. 8 ID detection monitoring module output

2) *Pests Detection:* it is based on PIR sensor with small lens size; it is used for detecting small bodies such as crop pests, based on this sensor spraying pesticides into the crops will be more precisely, instead of using the scheduled method. If the pests detected an alert email will be sent to the farmer to warn him with the need for pesticides. Interfacing sensor with BBB is shown in Fig. 4. The output of the script for pest's detection from Cloud9IDE of BBB is shown in Fig. 9:

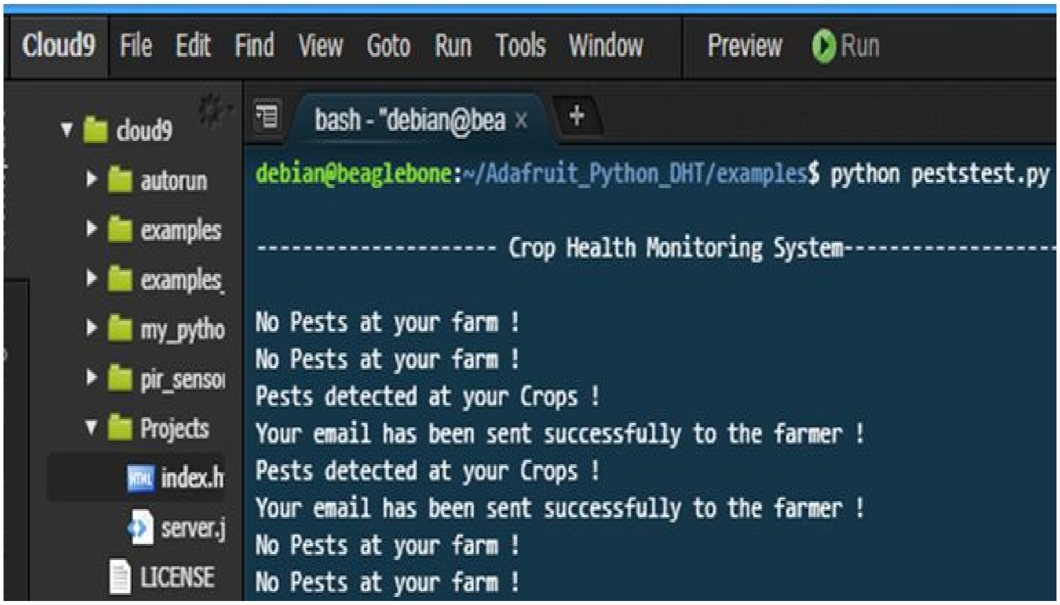

Fig. 9 Pests' detection monitoring module output

C. Weather, Water, and Soil Monitoring Module

There is a strong relationship between the weather, water, and soil parameters variations in the agriculture sector, because the increasing or decreasing in any one of these parameters will affect the other two parameters, so combined all of them into a one monitoring module is a good idea. This module which is based on BBB, DHT22 sensor, soil moisture sensor, water level sensor, raindrop detection sensor and colour detection sensor the components integration is shown in Fig. 10.

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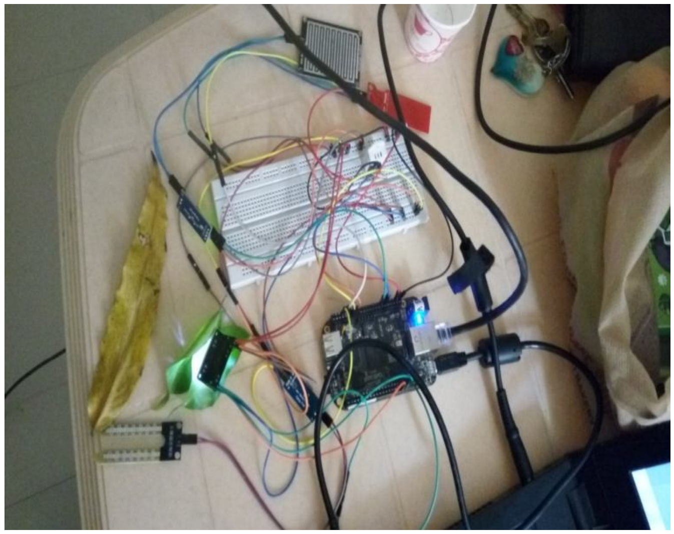

Fig. 10 Weather, water, and soil monitoring module

The algorithm for the proposed system is summarized in a flowchart to explain the system working principle as shown in Fig. 11

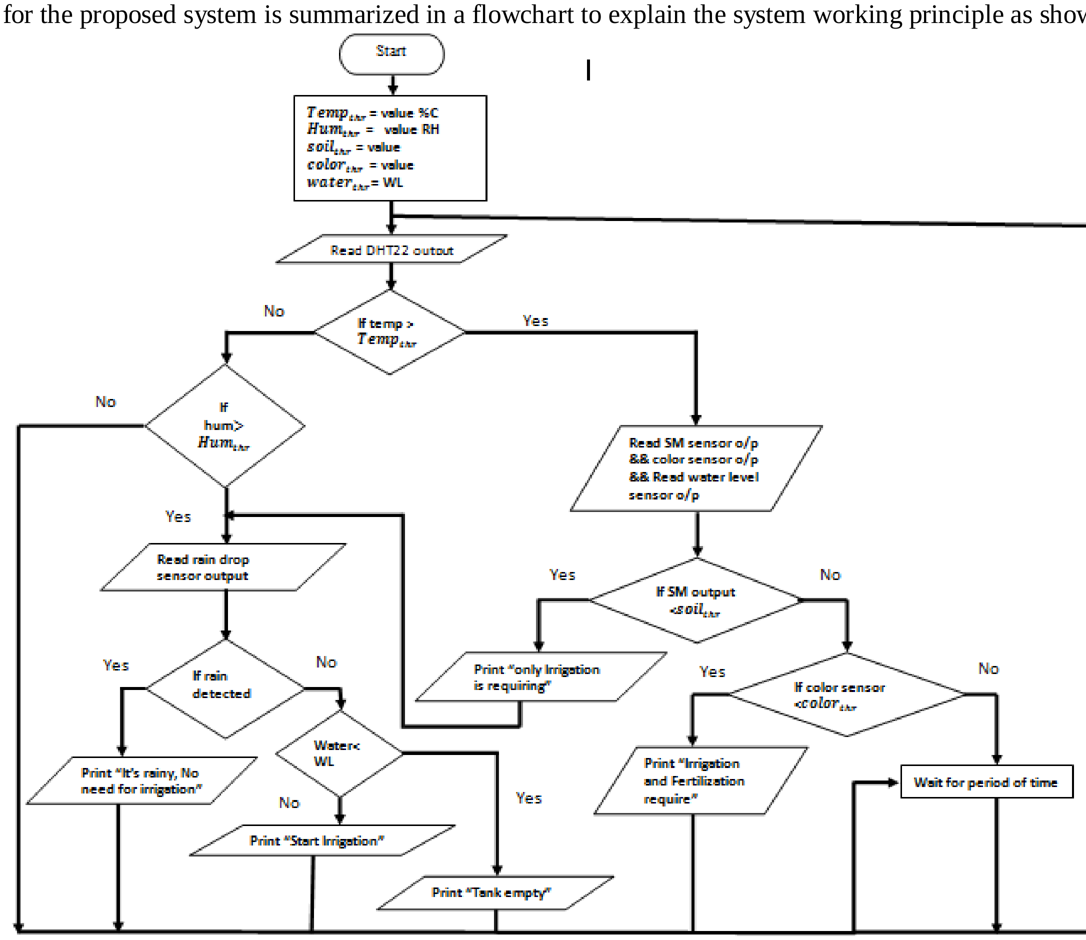

Fig. 11 Weather, water and soil monitoring flowchart

1) *Weather Monitoring:* It is based on the output of the DHT22 sensor; this sensor will measure the temperature and humidity of the climate if the weather temperature or humidity exceeding the threshold, an alert email will be sent to the farmer. The output of module script from Cloud9IDE is shown in Fig. 12

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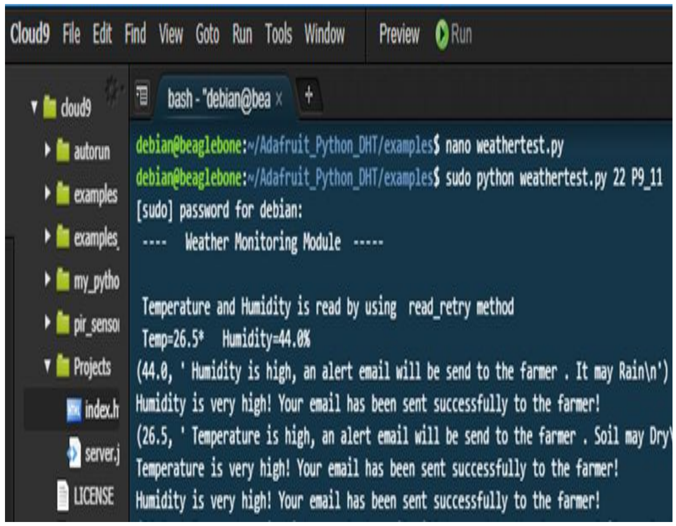

Fig. 12 Weather monitoring module output

2) *Water Monitoring*: It is based on the output of DHT22 sensor, if the humidity is high, it means there are some possibilities for rain weather, and then we have to check the output of the rain drop detection sensor if it is rainy, an alert email will be sent to the farmer to delay the irrigation process and avoid over irrigation for crops and conserve the water of the farm, if it is not rain so the output of water level sensor need to be checked, if the water level sensor output is less than the threshold value, an alert email will be sent to the farmer to inform him the tanks are empty and need to be filled soon, otherwise the water level in the tanks are acceptable and the irrigation process must be started. The output from Cloud9IDE of the script is shown in Fig. 13

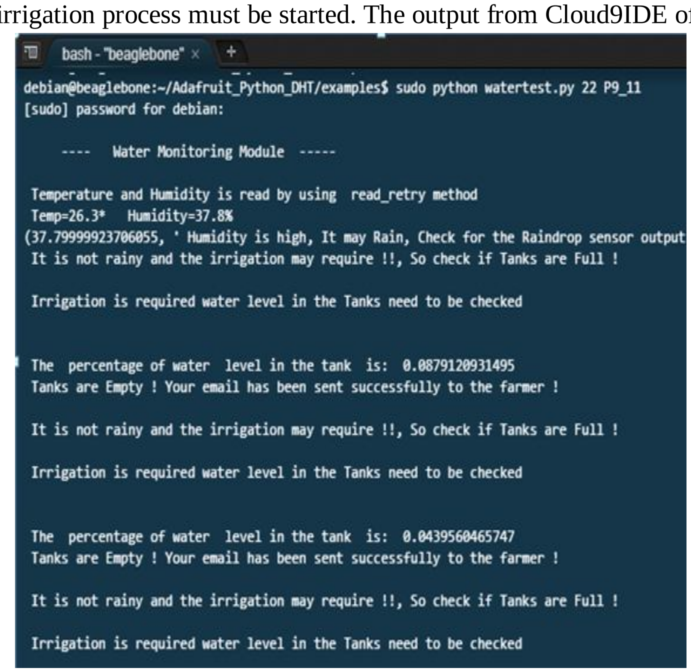

Fig.13 Water monitoring Module output

3) *Soil Monitoring*: It is based on the output of DHT22 sensor, if temperature is high, then soil may dry and the irrigation is required, in this case the output of soil moisture sensor will be measured to specify if the irrigation is required or not, if the irrigation is required, an alert email will be sent to the farmer to inform him to start the irrigation, so read the output of water level sensor is required, if the tanks are empty so an alert email will be sent to the farmer to fill the tanks. To apply fertilizer into the soil will be based on the output of the colour detection sensor, if the colour of the leaves changed into light green means there is nutrition deficiency in the soil, so an alert email will be sent to the farmer to inform him the fertilization is required. So there are five possible scenarios for the output.

V. WEB APPLICATION

To build a user-friendly interface enables the farmers to monitor their farms easily in form of Web app very simple; doesn't require training the farmers to use it. This Web application will consist of six buttons to monitor six of the farm parameters as shown in Fig. 14. All the modules scripts are running on specific schedule in the background using crontab. By clicking on each button will display the output of exact that button script with the date and time when the script run.

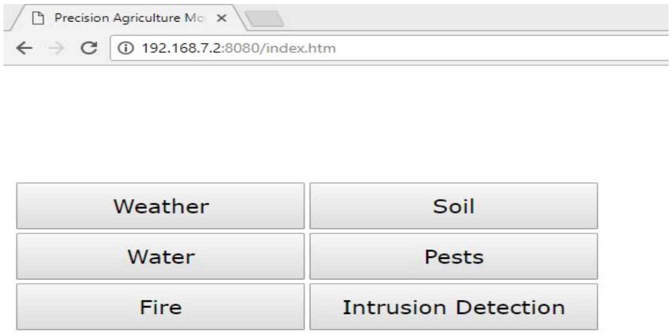

Fig.14 Web application page accessed from PC

Also, the Web app page can be accessed from smart-phone connected to the same network as shown in Fig. 15

Fig. 15 Screenshot for the web application page accessed from smart-phone

VI. CONCLUSION

The implemented system achieve the majority of its objective in terms of build real-time, cost-effective precision agriculture monitoring system, the system also act as a decision support system help to increase the productivity of the crops without affecting the quality, moreover the system will help to manage farm water resources precisely, and reduce the impact of chemicals by applying the fertilizer and pesticide based on the collected data. However, the output of color detection sensor affects the slight change in leaf position (offset), which may result in an inaccurate output. Also, the system will enhance the farm's security by detecting the intrusion and detecting the fire.

VII. ACKNOWLEDGMENT

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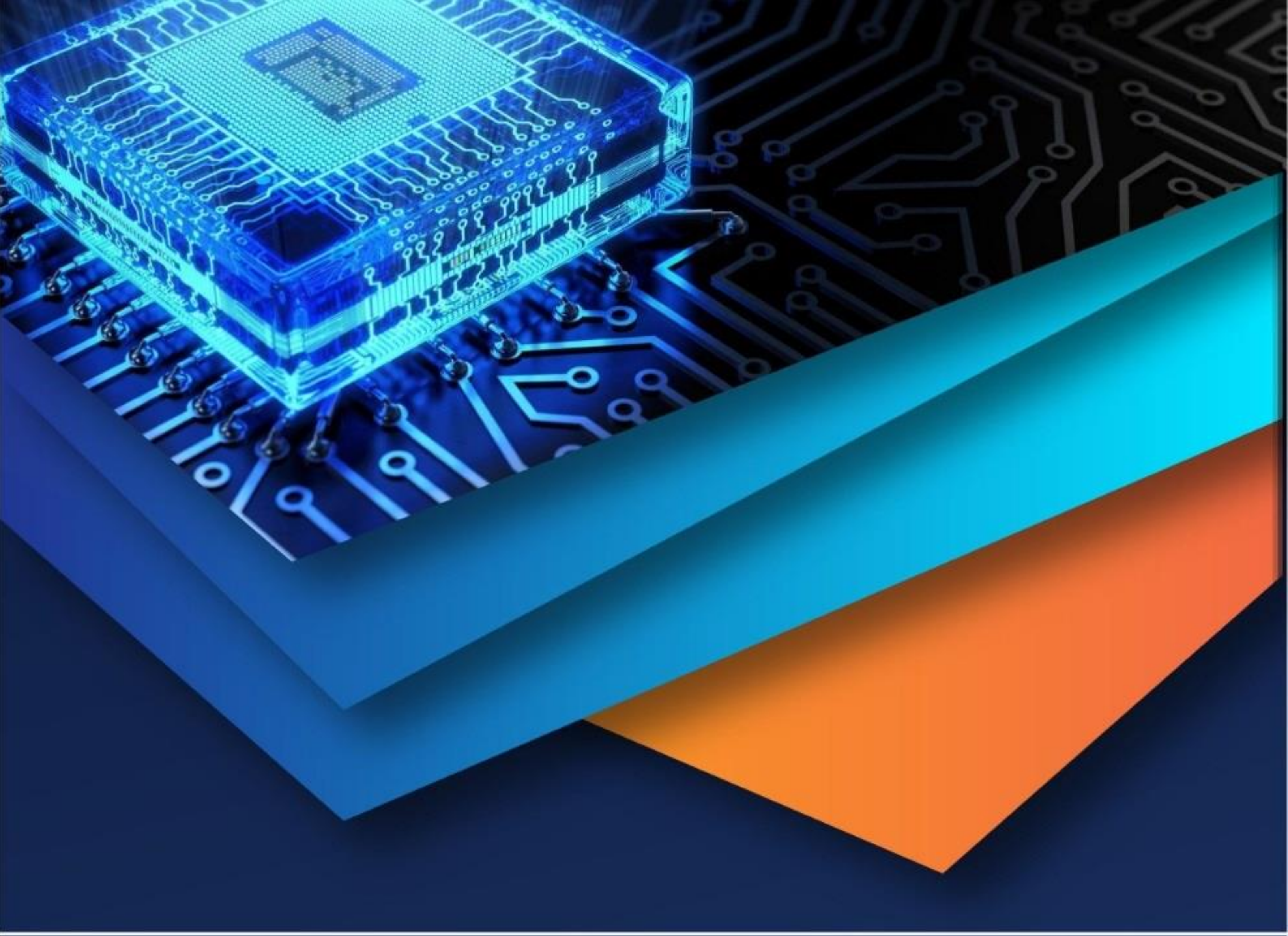

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