Implementation of IoT With Image Processing in Greenhouse Monitoring System

Tariku Birhanu Wudneh and V.Vanitha

Abstract: Greenhouse automation system using Internet of Things (IoT) is a technical approach that benefits farmers by the automation and control of the greenhouse environment including plants health monitoring. Farmers' activities in the greenhouse are considered important in terms of producing strategic food for the population. In general, greenhouses are usually affected by the weather and plant diseases, as a result, their yield can be minimized and thus income is reduced. Through the analysis of the current situation of small-scale greenhouses, this paper proposes a low-cost solution for controlling, identifying, and classifying of infected plant leaves and automation of agricultural greenhouse. Design and prototype development of the proposed project has been done using Raspberry Pi, NODE MCU SP8266, different sensors and MATLAB. The programming language, MATLAB, is used to classify infected plant leaves, and sensors have been used to measure temperature and humidity of the greenhouse environment. In addition, controlling of actuators have been attained through solid state relays in order to turn the water drip system on or off upon reaching the predetermined threshold value. Finally, the greenhouse farmers interact with the proposed system via the cloud-based platform. This greenhouse automation system will benefit greenhouse farmers by enabling them to automatically monitor and control the greenhouse environment without their direct supervision.

Keywords: IoT, Greenhouse Monitoring, plant diseases

I. INTRODUCTION

Internet of things (IoT) technology is impacting the world significantly. It is being employed in various sectors, and agriculture is one of them. Application of IoT ranges from small farm areas such as greenhouse to large farm that are being handled using conventional method. By using smart technologies, such as temperature sensor, soil humidity sensor and camera, productivity and quality of product can be enhanced by online monitoring and control of greenhouse environment. Control of greenhouse temperature and humidity can be achieved by automating pumps and fans using relay based on the threshold value.

The Internet of Things is a technology that uses smart devices, and it is connected to the Internet. Human intervention is not needed for data communication between IoT components and network [1]. Greenhouses are usually affected by an extreme weather condition and plant diseases, which are affected by factors such as temperature, humidity, soil moisture and amount of CO2.

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Gathering useful information of the individual factor's effect through constant observation is required to maximize crop productivity [19]. Productivity and energy saving can be optimized through optimizing the greenhouse climatic condition [18]. Implementation smart greenhouse based on IoT technology helps to monitor and control the climate without requiring the need for manual intervention. Moreover, IoT is a low-cost solution for monitoring plant health by identifying and classifying infected leaves using image-processing technique.

The purpose of this study is to design and develop an IoT based smart system to monitor and control greenhouse environment and crop health by using an IoT based application. The system can identify and classify of infected plant leaves and monitor temperature and moisture of soil in the greenhouse, and control pump and fan using automated mechanism based on their requirements and soil moisture in the greenhouse. This greenhouse monitoring and automation system will benefit greenhouse farmers by enabling them to do smart farming and increase their overall yield and quality of products by automatically monitoring and controlling the greenhouse environment without their direct supervision. In this system the greenhouse farmers interact via the cloud-based platform. This system will reduce manual intervention of farmers to determine their plant disease and enables effective inspection by utilizing knowledge of Experts.

I. RELATED WORK

From a technical point of view, the IoT presents a network of an uncountable number of globally connected objects -devices, sensors or actuators those are providing different services over the Internet, Agriculture is one of them. IoT benefits the agriculture to make smarter, nowadays most of the greenhouses are automated using IoT devices, those technologies are all on its toes to solve real-life problems and facilitate farmers more. Most of the scholars have done tremendous work on greenhouse monitoring system and plant leaf disease identification system independently. As greenhouse monitoring system using IoT number of novel works are done by researchers, on some of the novel works are introduced by Jyotirmayee Dash et al. have applied plant health monitoring using the NDVI (Normalized Difference Vegetation Index) to identifying healthy and non-healthy plants [2]. Bauer et al. use leaf area index (LAI) for monitoring of crop growth [3]. Rao, R. Nageswara et al. are done irrigation system in a low quantity of water [4]. Plenty of applications using IoT have been done like Kothiya, Rathinkumar H et al. farmland automation system including intruder detection and water pump controlling [5]. Mazon-Olivo, Bertha et al. for precision agriculture using Complex Event Processor (CEP) by observing incident pattern based on that making automatic decisions and notify to the end user [7]. Suma, Dr. N et al. using GPS technology and IoT devices to monitor overall security of the irrigation including leaf wetness [10]. Sreeram, K. et al. the technology GSM and DTMF are used for controlling the agricultural field [9]. Reza, Zarreen Naowal et al. using Android application and SVM stem diseases type of jute plant is identified [15]. Athukorala, Supun et al. monitoring and controlling the environment of remote greenhouse through mobile app and website [12]. The researchers have done and solver real-time problem using IoT and image processing separately. So that plants leaf disease identification systems are not integrated with IoT it runs standalone, So, whenever there is a plant disease problem in the greenhouse or farm it is difficult to figure out or monitor remote greenhouse immediately. And also, the greenhouse farmer doesn't get an early report about the plant's health. Hence detection of plant disease and monitoring of the greenhouse becomes so time-consuming. in this paper, we are worked on the implementation of IoT with image processing to control and monitor the remote greenhouse. Using various sensors in the greenhouse shown on description of the proposed system, data is collected from those sensors to control and monitor the temperature of the greenhouse, Moisture of soil in the greenhouse at the same time automate the watering (drip) of the crops based on their requirements and soil moisture in the greenhouse, on the other hand by capturing various plant leaves in remote greenhouse using camera and MATLAB image processing tool we tried to classify the leaf diseases using the classification method of MATLAB multi-class SVM (Support Vector Machine).

II. DESCRIPTION OF THE PROPOSED SYSTEM

Proposed IoT system composed of various electronic and electromechanical devices. Descriptions of the main components are given below.

A. Control unit

This microcontrollers or control unit are used to handle all the number of sensors deployed in this project and based on the threshold values they are responsible to decision-making. Input ports form microcontrollers are used to collect data from sensors. Whereas the output ports are used to actuation or to control the IoT device.

1. Raspberry Pi

In this project, Raspberry pi 3B+ is used as a controller to control the intended action including the actuator based on the input data gathered from the environment using various sensors and camera. Raspberry Pi is a small sized computer that can function as a desktop computer that can be used to build smart IoT devices [4]. This device is able to gather and process data and execute action as per the design specification.

Table 1:

Feature	*Pi 3 B+*
Architecture	ARMv8-A 64/32-bit
Ethernet	10/100/1000 (max 300) Mbps
Onboard WiFi	802.11, 2.4 and 5.0 GHz connectivity
Onboard Bluetooth	4.2
Input output Pins	40
Audio Output	3.5 mm Analog jack and Digital through HDMI
Camera Input	15-pin CSI (Camera Serial Interface)
Memory RAM	1GB

Fig. 1: Raspberry Pi 3 B+

2. NODE MCU SP8266

SP8266 is used as to collect data from sensors. it is an open source platform; this hardware design is open for edit/modify/ and build. SP8266 dev kit/board consist of ESP8266 WiFi enabled chip. The ESP8266 is a low-cost Wi-Fi chip it works on 3.3 volts TTL logic. Its I/O pins also provides 3.3 volts as output for other sensor devices. NODE MCU dev kit has Arduino like analog (i.e. A0) and digital (D0-D8) pins on its board. It supports serial communication protocols i.e. UART, SPI, I2C etc. in this project this SP8266 board is used to collect data from sensors and automate the greenhouse with the Raspberry Pi.

Fig. 2: Node MCU SP8266

B. Input devices

This IoT input devices are connected to the WSN to deliver the information or data they obtain from the environment over deployed sensors, or to allow different systems to arrive and act as the given command through actuators and motors.

1. Raspberry Pi Camera

5MP Raspberry Pi camera is used for capturing leaf images with a given period of time. It is connected to controller through Breadboard. It is capable to take with up to (2592 x 1944) pixel images and 1080p30 video. A dedicated CSi interface, designed specifically for interacting with cameras, is implemented to interface it with the Raspberry pi.

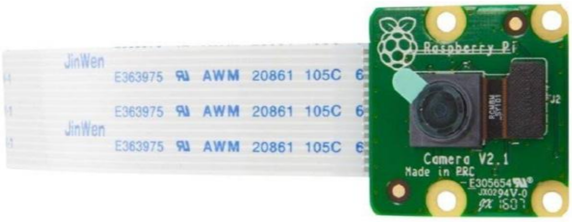

Fig. 3: Raspberry Pi Camera 5MP V1.3

2. Soil Humidity Sensor and Water Sensor

Soil humidity sensor is critical for automating agriculture based on IoT. It measures the amount of water in soil. The data gathered by it is used by the controller to decide whether to actuate pumps to water crops through relays as per the requirement through comparing it with the soil moisture threshold. This device operates on 3-5volts and communicates with Raspberry Pi via the one wire communication protocol.

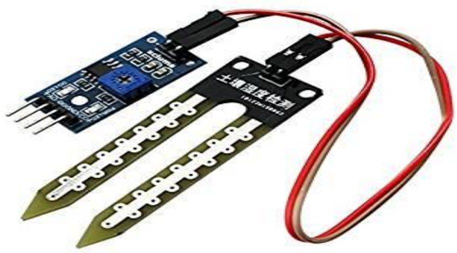

Fig. 4: Soil Humidity Sensor and Water Sensor

3. DHT11 Temperature and Humidity Sensor

This digital temperature and humidity sensor are responsible for capturing the temperature of the greenhouse and ambient humidity. This sensor can read temperatures and humidity between 0 and 50◦C and between 10% and 95% respectively using an NTC thermistor to measure temperature and HR202 to determine humidity. Similar to the Pi camera, it also interacts with the control unit using via the one wire communication protocol.

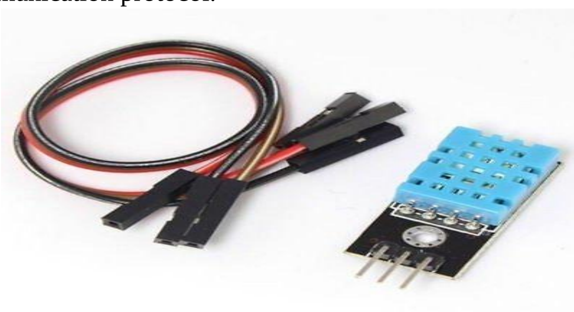

Fig. 5: DHT11 Temperature and Humidity Sensor

Moreover, apart from the aforementioned devices, the following components are also part of the proposed system.

- HDMI cable male to male.
- Cable jumper wire male to female
- RJ45 CAT5 ethernet LAN network patch cable
- Memory card: 16/32GB class 10 micro SDHC card
- Personal computer: minimum of pentium IV processor, hard disk up to 40 GB, GB RAM with monitor and mouse

III. GENERAL ARCHITECTURE

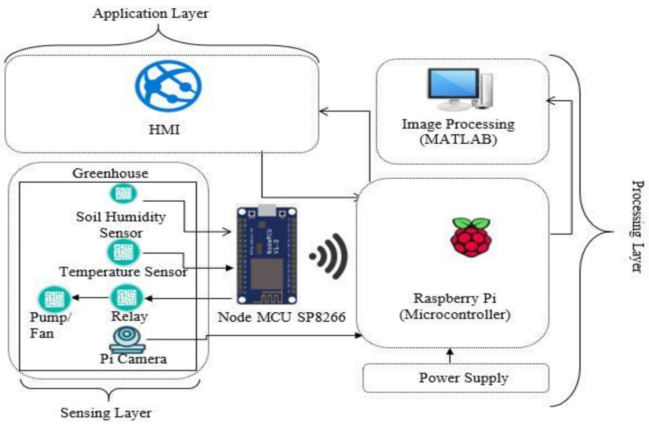

Fig. 6: General System Architecture

Figure 6 shows the general architecture of the system presented in this work, and it indicates the various sensing devices that are to be deployed to gather information about greenhouse such as leaf image, temperature and soil humidity. These sensors are interconnected, as demonstrated in the Figure 6, through WSN. They interact with a processing unit and the network so that the data can be processed, analyzed and stored. Various data analysis algorithms can be used to generate explicit information for the controller to take action according to the requirement.

IV. DATA FLOW DIAGRAM

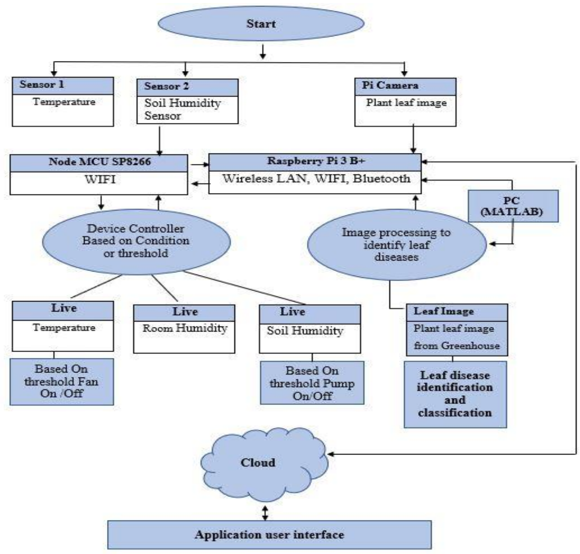

Fig. 7: Proposed System Dataflow diagram

The sensors, which are connected to SP8266 NODE MCU board, assess the condition of the real-world environment and sends information to the control unit, Raspberry Pi. It makes the decision by processing and comparing the data obtained using the seniors against the threshold values. The controller, then, controls the actuator in order to influence the real-world environment. For example, solid-state relay is used to turns on the water pump when the soil is dry or off when it is not. Similarly, pi camera is connected to Raspberry Pi to take pictures of leaves in the greenhouse for further disease identification and classification process. The values, which are acquired from sensors and camera, are stored in the cloud and computer. Farmers or greenhouse workers can see proper real-time results from the cloud.

V. RESULTS AND DISCUSSION

The IoT based greenhouse automation system has been designed and developed, and it has been tested to validate the result. Various greenhouse parameters, such as temperature, humidity, crop health etc. have been measured and analyzed. The findings from the tests are presented below.

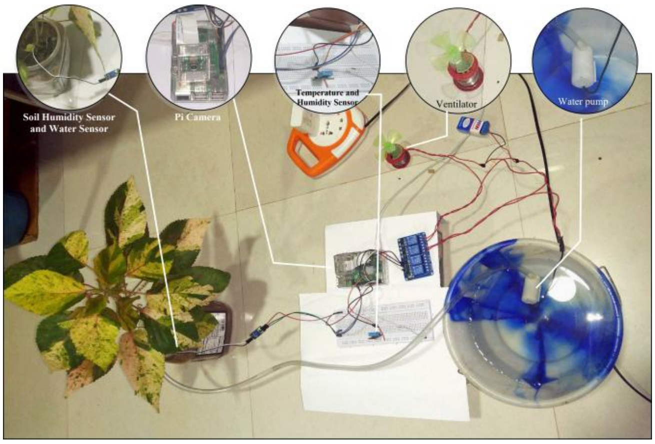

Fig. 8: Prototype arrangement

1. Temperature and humidity

The system is equipped with temperature sensor, and it has been used to detect the greenhouse temperature. Next, the output of the sensor has been given to the SP8266 NODE MCU and SP8266 send acquired data to Raspberry Pi, then, executes a specific algorithm in order to determine the action to be taken. Prior to using the sensor, it was calibrated using the known value so to make sure that it can capture the exact temperature. First, a model greenhouse has been constructed and its temperature has been measured. The measured temperature was 28.5 degree Celsius. The system has not taken any action. After waiting sometime, another temperature reading has been taken, and it was 33 degree Celsius. This time, fan has been turned on via the relay. And it runs until the temperature drops to below 30 degree Celsius and turned off. In addition, a soil humidity sensor has been deployed to measure soil humidity. When the output of soil humidity sensor has was less than 30, the system has turned on pump to water the greenhouse. Whereas, when the temperature was between 30 and 70, the system has not taken any action. However, when the measured humidity is between 70 and 95, it turned off the water pump.

Table 2:

Greenhouse water drip based on Soil Moisture value		
Soil Moisture /Input	**Status**	**Action /Output**
0 ~ 30	Dry Soil	Pump ON
30 ~ 70	Humid Soil	No action
70 ~ 95	In water	Pump OFF
Greenhouse temperature based on temperature value		
Temperature/Input	**Status**	**Action /Output**
27 °C to 30°C	Ideal	No action
> 30°C	Hot	Turn ON the fan
< 30 °C	Cold	Turn OFF the fan

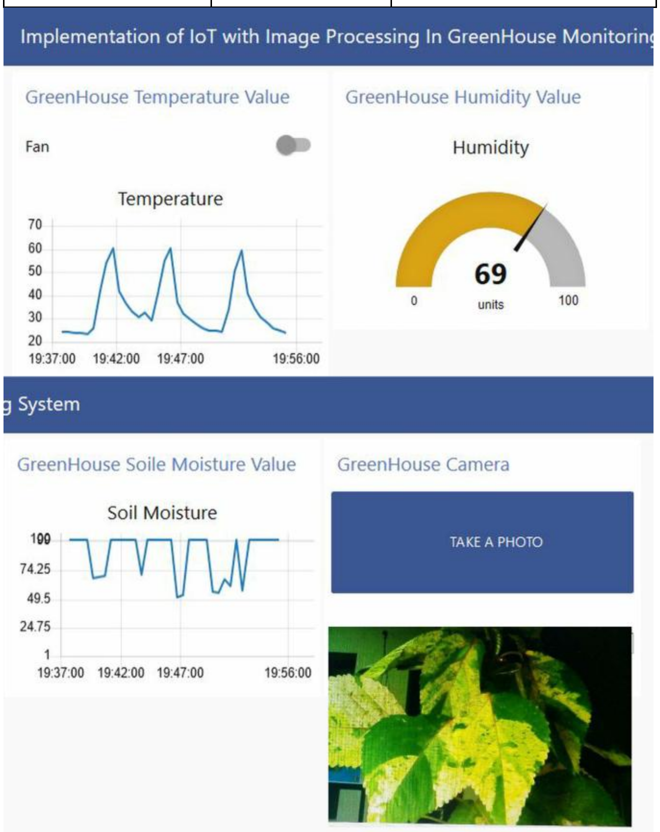

Fig. 9: Greenhouse Temperature, Humidity, Soil moisture and Greenhouse plant leaf (User interface).

2. Monitoring plant health

In a remote model greenhouse plant leaf has been captured using Pi camera within a specified period of time. The camera sends images to Raspberry Pi via UART serial communication. The Raspberry pi, then, sends it to a remote image-processing unit for monitoring plant health by identifying and classifying infected leaves using MATLAB.

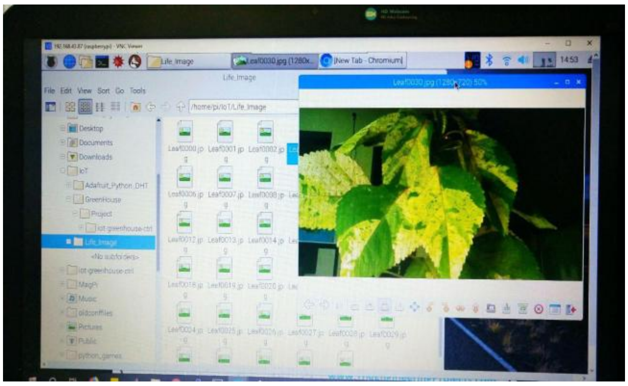

Fig. 10: Life image captured by Pi camera within a specified period of time.

Training the system using JPEG image of four common leaf disease such as Alternaria, Alternata, Anthracnose, Bacterial Blight and Cercospora is done to creates a dataset. These images of diseased leaves are taken from various trusted online sources like (Plant Village dataset) [19]. The system contains more than 60 disease types to compare with the health condition of the crop. Therefore, the performance of the system was tested by capturing images using Pi camera and processing it with the processing unit, and the system was seen to effectively identify, classify and determine the health condition of the plant in the greenhouse. The working of the plant health-monitoring module is shown in Figure 11 below.

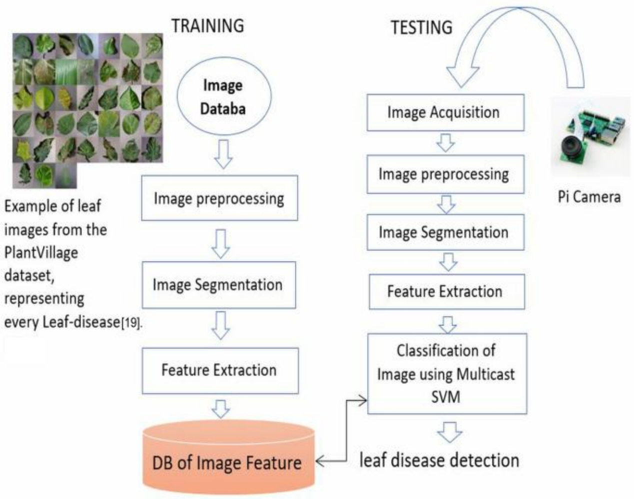

Fig. 11: Leaf disease detection and classification DFD

Therefore, once the system receives images, it is enhanced so that the image-processing algorithm can easily interpret it. Then, image segmentation, which is digital image partitioning into number of pixels, is carried out to simplify the representation of the images so that it can be easier for further analysis. After segmenting the images, color features and shape features extraction is carried out through MATLAB feature extraction algorithms in order to build feature vectors. Then, classification of images using Multicast SVM is performed. Finally, the processed images is compared with the types of leaf disease from the database of the system to determine the type of disease the leaf is victimization, the aim of this study work is to determine the health condition of the leaf and, if it is infected, the system will specify the type of disease that infected the plant and the level of infection as shown in Figure 12.

The output of the image processing system is identified leaf diseases and class of the diseases family name. This system should also have a convenient interface where the user can control all the drives that will be used in the automated structure. Given that these activities will be carried out remotely using cloud as a means of communication, this feature will bring convenience to the farmer.

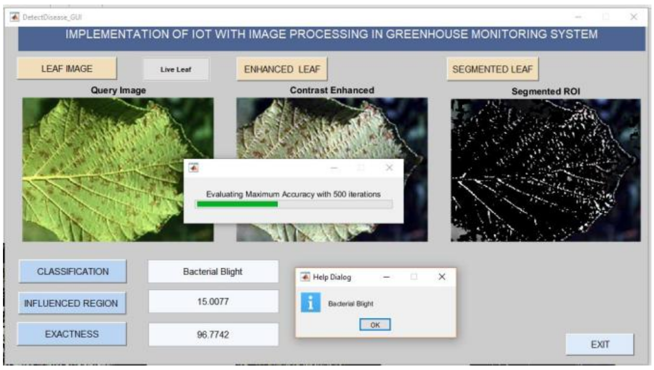

Fig. 12: Detecting plant leaf disease (MATLAB)

VI. CONCLUSION

In this project low-cost IoT based solution that monitor greenhouse condition such as Temperature, humidity and plant health is developed and tested. Various I/O devices and algorithms to identify and classify infected greenhouse plant leaves have been implemented. The system is efficient in terms of monitoring and controlling the greenhouse environment. This system is simple, portable and affordable to most greenhouse farmers. Therefore, it can be used to improve quality and productivity of agricultural produce. In addition, multiple cameras can be deployed to monitor and control large greenhouse area as the system cost is cheaper. Besides enhancing the productivity of the farmer, the proposed system can change the traditional way of identifying leaf diseases from manual observation to IoT based plant health monitoring.As future work, it is recommended that instead of fixing the camera module in one place it can be made move from one place to another by placing it on a custom camera slider so as to capture different leaf images in the greenhouse. This helps to monitor the overall greenhouse plant leaves health.

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