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IOT Architecture for Real Time Maize Stem Borers' Detection and Capturing in Precision Farming

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Abstract

The emergence of Information and Communication Technology (ICT) has brought tremendous change in Precision Farming. The invention of these technologies enhanced farming techniques for optimal yield of crops and its management in the agricultural sector. These technologies aid farmers to survey, monitor and collect data remotely from the farm and communicate the same anywhere in the world. For crops in the farm to grow healthy, they need caring and monitoring from insects' attack. Farmers adopt many measures to drastically reduce the influx of these insect pests in the farm. However, the measures put in by farmers to carry out monitoring are still not enough because monitoring requires the presence of the farmers in the farm and scouting for the insects' presence during the developing stages of the crops. It was recently announced of the aggressive insect pests (stem borers) that attacked maize crops and caused poor yield of the maize in that season. The rate at which these insect pests (*Spodoptera* species) migrate in numbers and eat the leaf, ear and stem of maize within few days is alarming. This work presents IoT architecture for real time maize stem borers' detection and capturing in precision farming. This system would monitor for the presence of these insect pests in the farm (e-scouting) and communicate to the farmers remotely thereby relieving them visiting their farms frequently. The IoT system hardware has two modules. The first module is the slave device that consists of the camera, motion sensor, super light LED, battery, GPS, antenna, etc. whereas the second module, the master device, comprises of the power supply, Jetson Nano, 4G wireless router, Wi-Fi dongle, SD card, etc. Both modules were designed and integrated for use in detecting and capturing the targeted maize insect pests in the farm. The slave devices would be installed in the farm at different coordinates and linked to the master via Wi-Fi technology and antenna. The master device accepts the detected insect pest data, processes and recognizes the insect through machine learning algorithm/trained model and finally sends to dedicated cloud storage for further use by farmers. The prototype IoT system was successfully tested at University of Port Harcourt's Farm for Teaching and Research. This hardware would greatly aid decision making by farmers in ensuring that these maize stem borers are recognized and controlled in precision farming.

Keywords: IoT, Raspberry Pi, Precision Farming, *Spodoptera* species, Jetson Nano, ICT, Maize crop, GPS, Antenna

1. Introduction

The innovative invention of IoT technology has enhanced the farm management system used by farmers to ensure efficient crops productivity in precision farming. This farm management system requires the use of network sensors, embedded system and data communication to promote crops monitoring system in the farm, which has yielded better result. In precision farming, sensors are used to gather real time data from the farm which is processed by IoT system in order to help farmers make decisions to improve on the farm management system as discussed in (Telit, n.d). The IoT-based applications have been used in Agriculture for data collection, monitoring and surveillance as pointed out and a lot of positive achievements recorded.

Rodrigo *et al* (2017) developed an IoT device for remote monitoring system in precision agriculture. Their designed system comprised of sensors for monitoring the temperature and humidity of the soil, Global positioning system (GPS) for capturing farm location coordinates, soil electrical conductivity and luminosity and ZigBee for communicating the data to the remote end via radio wave. During the system development stage, soil testing and local climate measurement were conducted in Sao Paulo Brazil for components integration that would improve on irrigation and crop health monitoring and control system. They pointed out that further research is going on to improve on the energy consumption of the developed IoT system. Also working on enhancing the system to help in detecting fire in the farm crops and promote irrigation management system.

Ms.Nilam *et al* (2017) presented IoT based early crop disease detection and monitoring in large farm environment. Their work discussed various types of diseases on the plant leaf that could cause growth problems during crops developing stages. These diseases sometimes might not be visible to human eyes but directly affect crops in the field. The system is used to automatically detect and identify the diseased part on the leaf images and classify the plant leaf disease using image processing techniques. Some important steps are used for detection like feature extraction, segmentation and clustering leaf images for efficient disease detection and for classification of images, genetic algorithm was used. The proposed model would help to reduce efforts or hard work of farmers on monitoring big farms and related diseases. The results show the difference between healthy leaf area and infected plants leaf area. Sensor devices plays an important role in collecting data as image of plants and plant leafs for the monitoring system. The approach is based on image processing, K-Mean clustering and Artificial Neural Network (ANN). This work would enable farmers to get the information about what kind of disease their crop is infected with,and the required fertilizers for the particular crops.

Manoj *et al* (2018) developed an unmanned aerial vehicle IoT based system for application in agricultural sector. Their primary focused was to design a remote controlled drone for spraying water and chemicals in the farm thereby eliminating human intervention in order to avoid health challenges. The proposed system would effectively reduce manpower and time for spraying these chemicals and enhance crop productivity. They further discussed that in India, pesticides and fertilizers are usually used to save the crops from pests attack and improve on the crops yield. The spraying of these chemicals is done by human and many deaths have been recorded yearly. The number of deaths and health challenge caused by direct exposure of these chemicals (pesticides and fertilizers) to human being was recorded to be over a million which has led to the development of the UAV IoT based drone spraying system.

Arnab *et al* (2018)developed drone (Unmanned Aerial Vehicle-UAV) for agricultural use to enhance crop yield using IoT. They discussed that UAVs have gained more attention due to their equipped capabilities in solving agricultural problems. The designed drone composed of various sensors for effective crops monitoring in precision agriculture. For further improvement of their work, integration of Raspberry pi 3 with Internet of Things and machine learning were recommended.

Arockia *et al* (2018) presented an IoT based Support Vector Machine (SVM) technique for crops fungal detection in agricultural field. In their report, Sensors were integrated to help monitor the air temperature, relative air humidity, rainfall and wind speed and send the real time data to the cloud for processing in order to detect the presence of the fungal at its early stage. The SVM, one of the machine learning algorithms stored in the cloud server was used to predict the presence of the harmful fungal disease in a crop to assist farmers to use the recommended control measure to improve on the farm management system for increasing crops productivity. They further stated that the use of their system (IoT) to perform such operation would go a long way in preventing fungal spread early and help famers use the correct control measure in combating the diseases.

2.0 Real Time IoT Architecture

The Internet of Things (IoT) architecture for real time maize stem borers' detection and capturing is designed using top-down approach. The entire system is divided into four major sections namely slave device, master device, mobile app and cloud server as shown in figure 1.

3.0. IoT Slave Device

The IoT slave device is used to detect and capture images of the insect pests (stem borers) all through the day and night in the maize farm. This device consists of Raspberry Pi and camera, motion sensor, super light LED, battery, GPS and antenna. The slave device parts are installed at various coordinates in the maize farm for insect pests' detection and capturing. The parts of the slave device are discussed in details below.

3.1 Embedded Circuit Board & Wi-Fi Technology

The Raspberry Pi 2 board(figure 2) is a device used for maize stem borers image processing and video streaming. This device accepts input from sensor, camera and GPS receiver and processes them. The camera connected to the Raspberry pi is activated only when the Raspberry pi device receives signals from motion detection sensor. The image/video file captured and processed is stored in the SD card and sent to the Jetson Nano via Wi-Fi dongle. The Raspberry Pi 2 runs on Raspbian operating system, a version Linux and a modified version of Debian. Preferred language is Python which is used to develop the programs that control the motion sensor, GPS, camera and LED.

Wi-Fi technology uses IEEE 802.11 standard and operates at frequency of 2.4 GHz for data transmission and reception. The technology uses the frequency band from 2401 to 2484 MHz with a communication distance of 100m.

3.2 Passive InfraRed (PIR) Motion Detector Sensor HC-SR501

PIR Motion Detector Sensor HC-SR501 (figure 2) is used to sense and detect motion of the insect pest range from 3m to 7m in the farm. It is configured to sense the presence of these insects and send signal to Raspberry pi for quick activation of the camera to capture image or video the insect.

3.3 IoT camera

The IoT camera is deployed to take the image of the insect pests or video of the insect and send to the embedded microcontroller for processing. The camera has high quality image sensor for sharpness and it's triggered by motion sensor after sensing an object (maize insect pests).

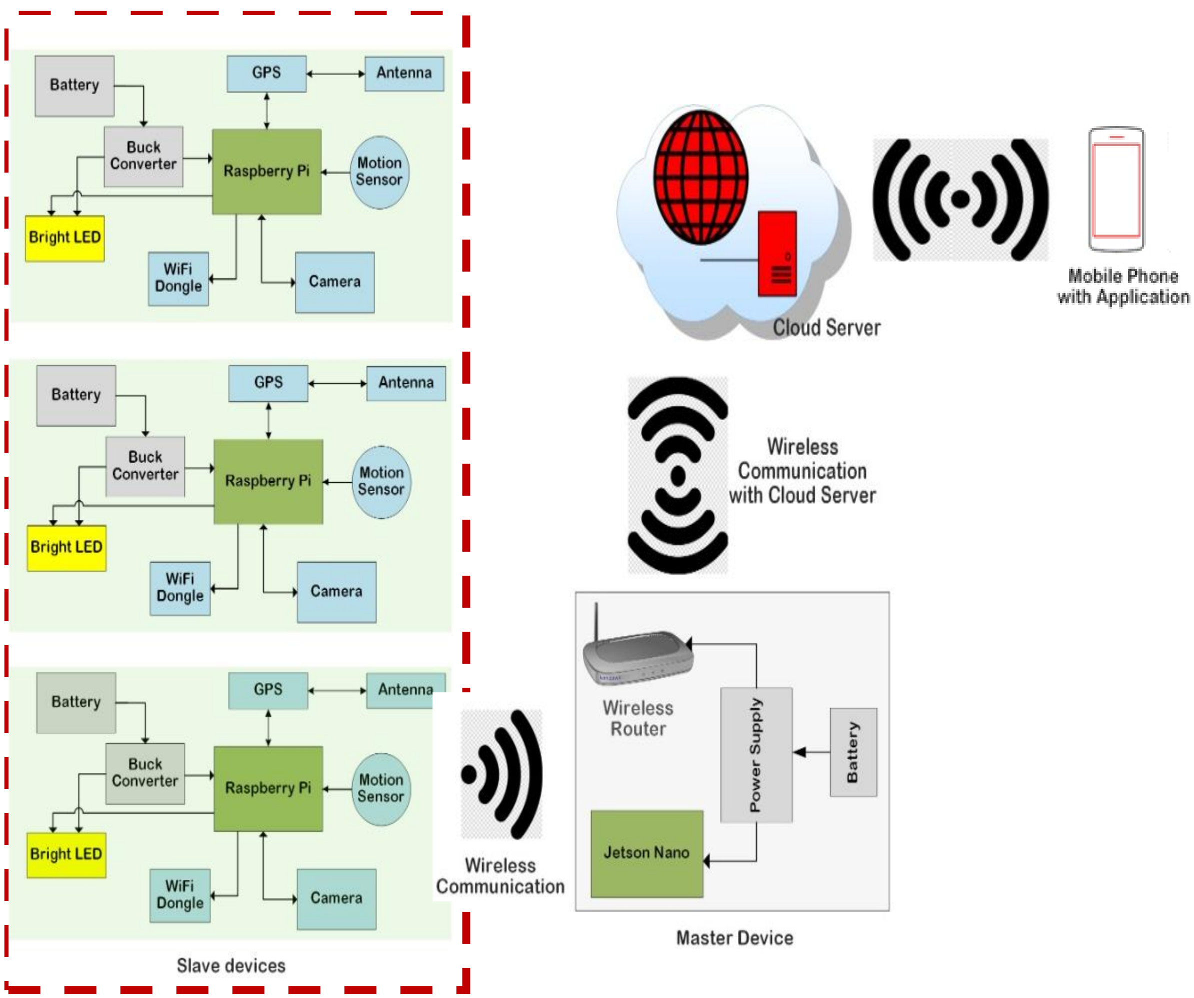

Figure 1: IoT Architecture for real time maize stem borers' detection and capturing

3.4 NEO 6m/7m/8m Global Positioning System (GPS) with Antenna

NEO GPS (figure 2) is used to determine the position of the slave camera that captures insect pests in the farm. The determined position information of every camera is used to tag the direction from where the insects captured in the farm are coming.

3.5. **Super Bright LED** is used to improve luminance within the maize farm to enable the motion detector sensor operate effectively at night. It also provides illumination to aid camera's image and video be sharp, bright and clear. The super bright LED requires 3.5V for its operation and is shown in (figure 2).

3.6 Battery Jack with charger

Battery Jack with charger (figure 2) is used to power the Raspberry Pi board which then powers every other component connected to it such as motion detector sensor, GPS, camera, super bright LED etc. Two Lithium batteries 16340 (rated 3.7V each) are inserted in the jack.

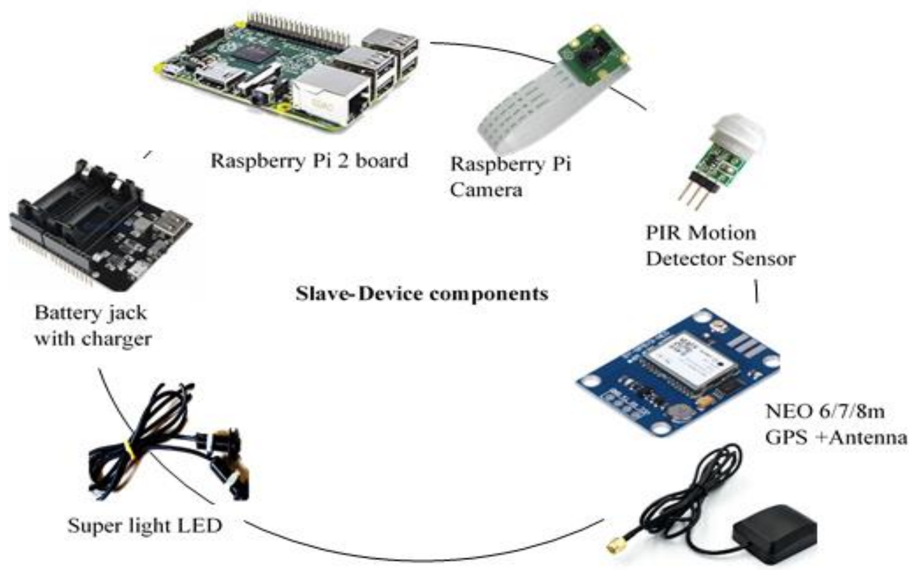

Figure 2: Slave-device components

4.0 IoT Master Device

The IoT master device is used to receive the captured insect image data, process and recognize them and then send to the cloud server via 4G wireless router for storage and farmer's visualization. This device consists of HRB DC power supply, Jetson Nano, and 4G wireless router. The master device is installed anywhere in the farmland and designed to access data from multiple slave devices. Parts of the master device are discussed below.

4.1 HRB DC Battery

HRB DC battery (figure 3) is used to supply voltages to Jetson Nano board and 4G wireless Router. The battery was chosen because of its power rating and it is rechargeable. It allows 6000miliamp current to flow per hour and can last long before discharging depending on what is connected to it.

4.2 Image Recognition device

This device (NvidiaJetson Nano) shown in figure 3 is used for image recognition because of its equipped capabilities. It has features that make it possible to carry out large computations with accuracy. The Jetson Nano receives multiple captured images/videos clips from various slave units and processes them to detect the insect pests via trained machine learning algorithm/model. It has WiFi adapter for wireless communication with 4G wireless router and SD card for storage of detected species images.

4.3 4G Wireless Router

4G wireless router (figure 3) is a superfast internet service that provides high-speed internet service connectivity around the farm. The Jestson Nano connects to it to send the recognized insect pest images to the Google cloud platform/server for storage and visualization by farmers. The Router device operates on 2.4GHz frequency.

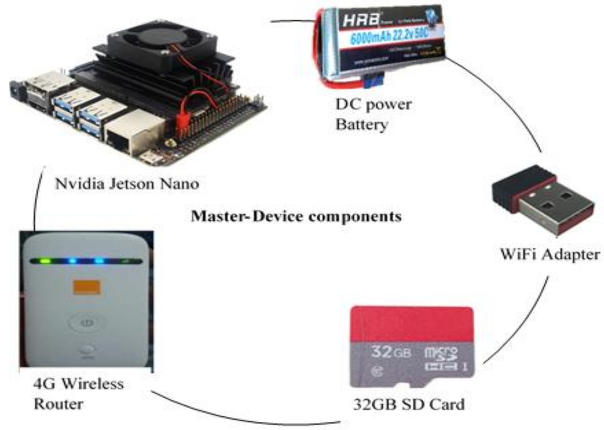

Figure 3: Master-device components

4.4 Google Cloud Platform

The Google Cloud Platform is deployed as an Infrastructure service (Iaas) to store all the predicted maize insect pests (stem borers) in a secured platform. The Infrastructure as a service (Iaas) provides virtualized computing resources over internet that are used to store, process and communicate the predicted stem borer to the farmers' mobile app. The Jetson Nano sends the predicted *Spodoptera*species to the Google Cloud Storage bucket (figure 4) for storage. Immediately the Google Cloud Storage bucket receives any insect pest data, it triggers the Google function that activates the Cloud pop-ups to send message alert to the farmer informing them about the newly found insect for visualization.

Figure 4: Google Cloud Server

4.5 IoT Communication Medium

The slave device communicates the detected and captured image of the insect species via unguided medium to master slave for processing and recognition. The communication link between the slave devices and master device is one-way and that of master device and Google cloud server is two-way as showcased in figure 1. The wireless communication is possible because of the Wi-Fi Technology added to the Raspberry pi and Jetson Nano boards which operate at a frequency of 2.4GHz.

5.0 Programming Languages used

The object-oriented programming language was used to write various instructions that perform the required operations successfully. The programming languages used are python and BASH.

5.1 Python Language

Python has been a language of choice with ease of use due to its readability and dense syntax.Programmers express concept with more easethan using other languages. Python was used to program the Raspberry Pi for motion sensing, image capturing, and transfer to Jetson Nano. It was also used to program the Jetson Nano for insect pests' recognition and classifications. The Jetson Nano manages and controls the multiple inputs sent from slave devices via Wi-Fi, processes them, and predicts the specie of insect pest captured in the farm. Also, the same Python codes are written to enable transfer of the predicted insect pests to the cloud for storage and farmers alert. The Pycharm/Anaconda IDE is used with python 3.8.2 interpreter to write and execute the hardware program codes as shown in figure 5.

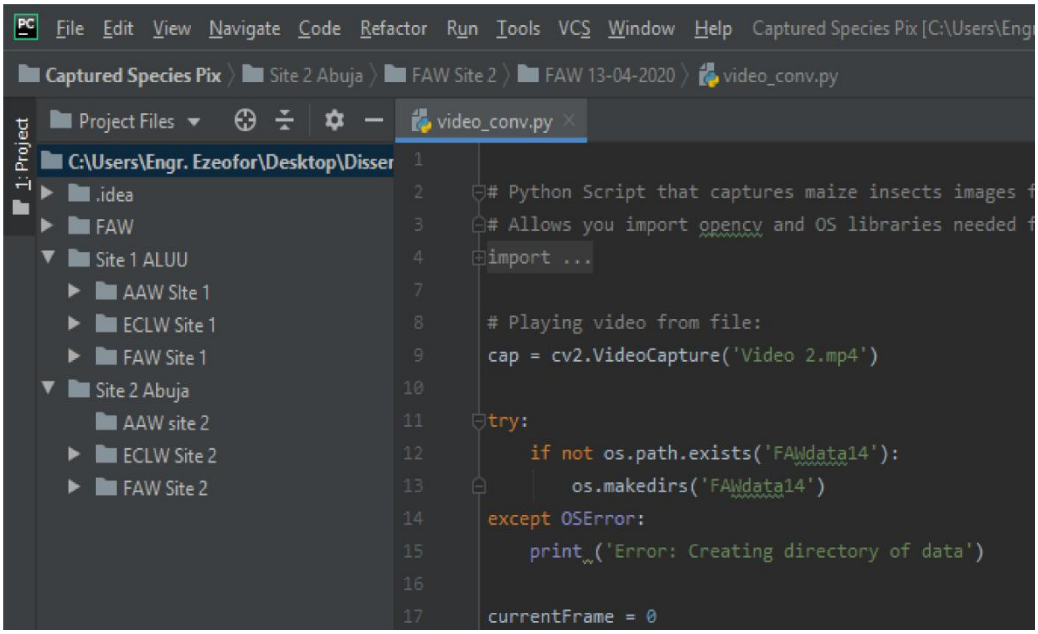

Figure 5: PyCharm IDE used to write Python scripts for slave devices

5.2 BASH Language

The BASH language is used to make the Python scripts start as the Raspberry Pi boots and ensure constant WiFi connection as shown in figure 6.

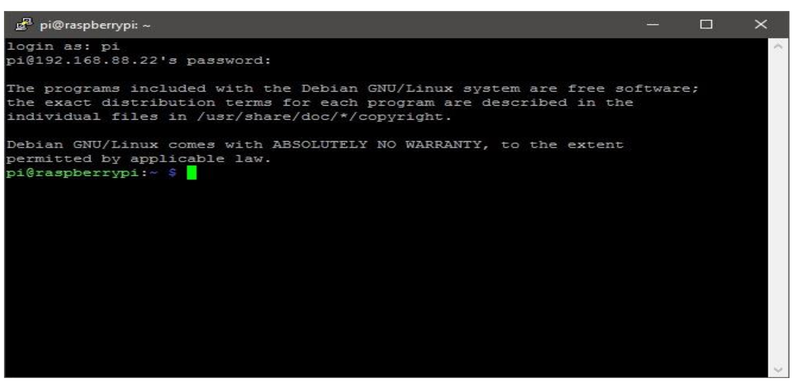

Figure 6: BASH environment

6.0 IoT Slave and Master Algorithms

6.1Slave Device Algorithms and Flow Chart

The Algorithm that enables the slave device to monitor, sense object motion, make a 10 seconds video clip, save and finally send to the Jetson Nano for further processing and recognition of the object is as follows:

Step1: Start the slave device
Step2: Search for registered Wi-Fi Network
Step3: Is registered network found and active?

No; Go back to step 2
Yes; Go to step 4
Step4: Connect to Wi-Fi Network
Step5: Check for Camera
Step6: Is camera connected?
No; Jump to step 5
Yes; Move to step 7
Step7: Check for motion sensor
Step8: Is motion sensor connected?
No; Jump to step 7
Yes; Move to step 9
Step9: Check for GPS module
Step10: Is GPS module connected?
No; Jump to step 9
Yes; Move to step 11
Step11: Is motion detected?
No; Jump to step 11
Yes; Move to step 12
Step12: Is the weather Dark?
No; Move to step 13
Yes; Turn the Infrared LED ON and go to step 13
Step13: Capture 10 seconds video clip
Step14: Read GPS coordinates from GPS module
Step15: Save video with date, time and GPS coordinates
Step16: Is infrared LED ON?
No; Go to step 17
Yes; Turn the infrared LED OFF and go to step 17
Step17: Send video clips with date, time and GPS coordinates to Jetson Nano
Step18: Delete the Video clip
Step19: Go back to step 11

6.2 Master Device Algorithms

The Algorithm that enables the master device to receive captured image of insect pest from slave device, use developed model to classify the insect and finally send to the Cloud server for storage is as follows:

Step1: Start the master device
Step2: Search for registered Wi-Fi Network
Step3: Is registered network found and active?
No; Go back to step 2
Yes; Go to step 4
Step4: Connect to Wi-Fi Router
Step5: check for image insect pest file (to be sent by the slave devices)
Step6: Is image insect pest file received?
No; Go back to step 5
Yes; Go to step 7
Step7: Use developed CNN model to classify the species
Step8: Is the insect maize insect?
No; Delete and go back to step 5
Yes; Go to step 9
Step9: Send the species to the Google cloud server for storage and go to step 10
Step10: Delete the image and go back to step 5

The flowchart of the slave device for the above presented algorithms is shown in figure 7a.

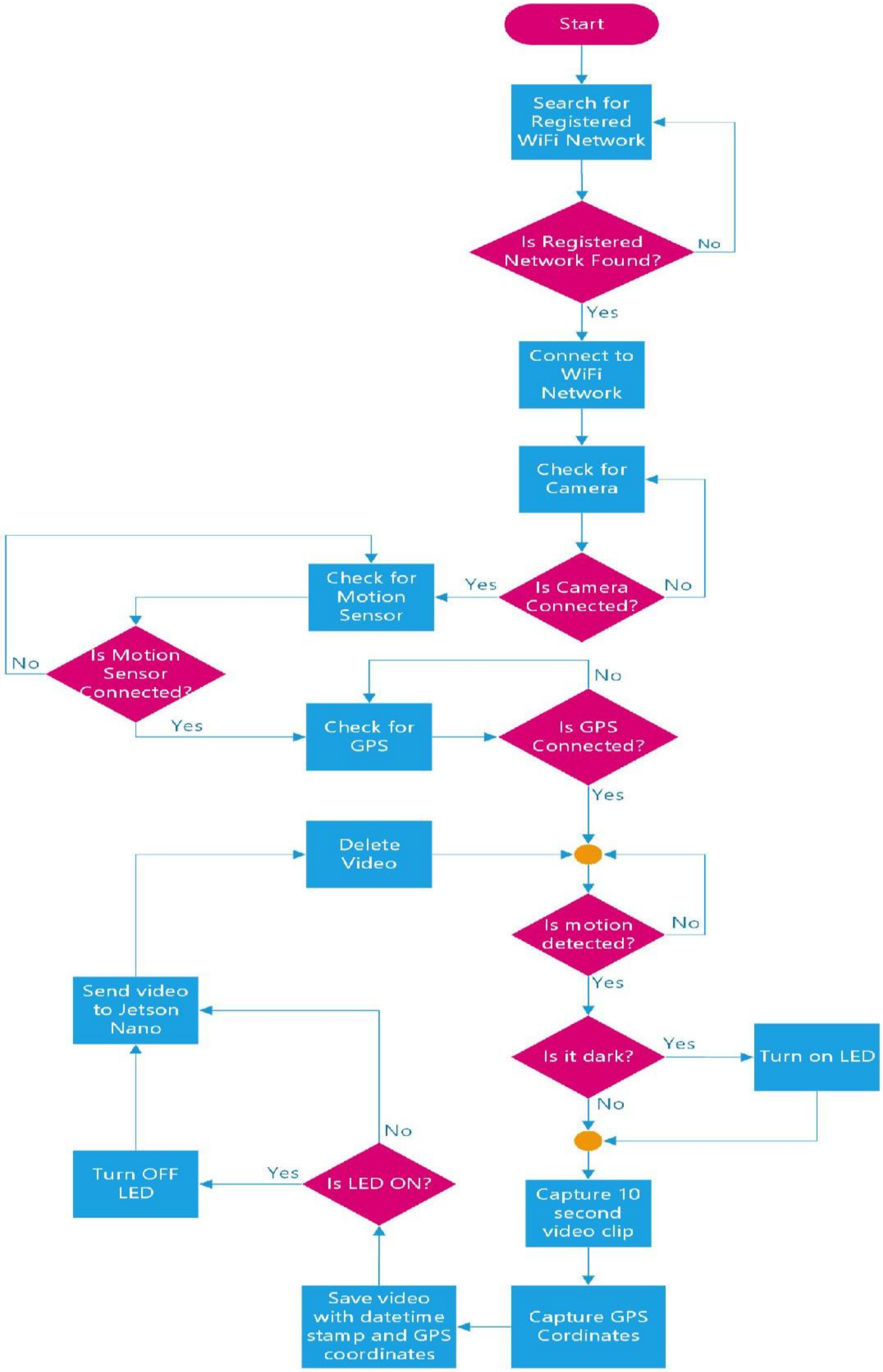

Figure 7a: Slave device flowchart

The flowchart for master device for the above presented algorithms is shown in figure 7b.

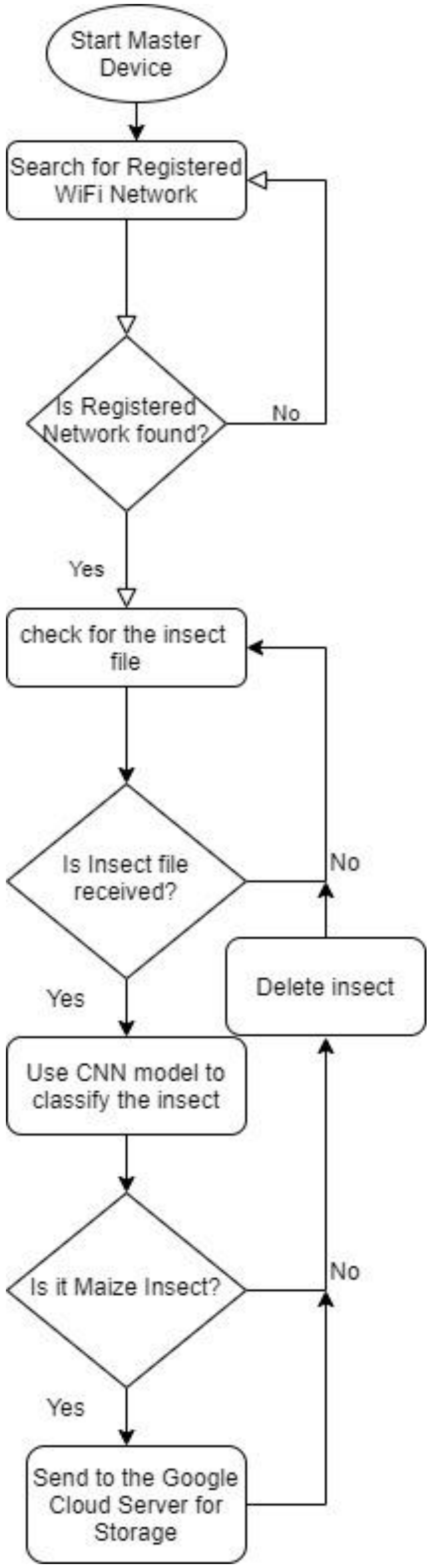

Figure 7b: Master device flowchart

7.0 IoT circuit diagram and its operation

The IoT circuit diagram comprised of the slave and master devices. The design was done using PROTEUS software. The slave device circuit diagram (figure 8) shows clearly how GPS, motion sensor, voltage converter, relay, WiFi dongle, raspberry Pi camera are connected to the raspberry Pi board. When the IoT system is installed in the maize farm at various locations, the slave device motion sensors monitor maize insect pests that might come around. The moment any insect flies around a motion sensor, it senses the presence of an object and sends signal to the raspberry pi to switch on the super light LED and trigger the raspberry pi camera to capture the image of the insect. The captured image, time, and location are sent to the Jetson Nano for classification and recognition.

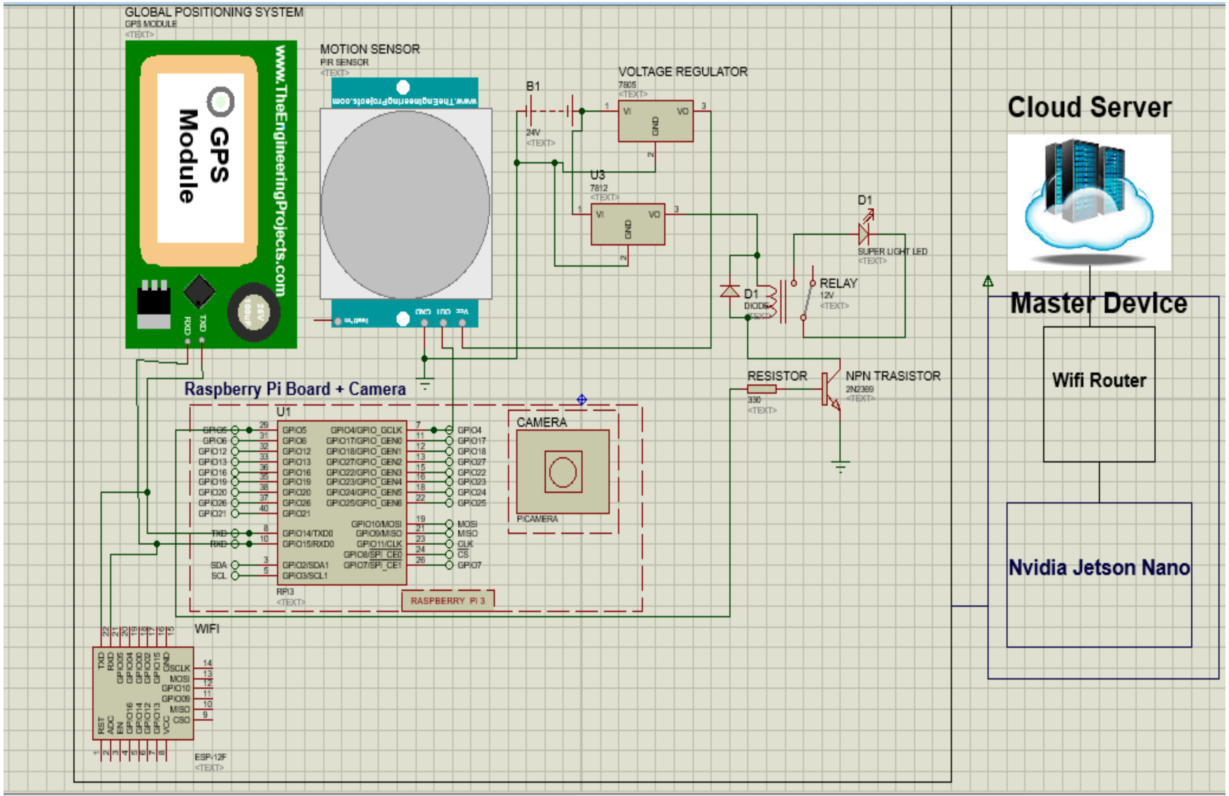

Figure 8: Slave and master devices Simulated Circuit diagram in PROTEUS

The master device (NvidiaJetson Nano) receives the insect pest image from the slave device and then invokes a developed model (an integrated convolutional neural network model) to classify the species. The species, if recognized are sent to the cloud via wireless router for storage. The farmer uses his/her Maize App to request for the stored *Spodoptera*species for visualization and further actions.

8.0 IoT Hardware System Test and Analysis

Both slave and master devices were assembled and tested. Raspberry pi board interconnects all the components of the slave device as shown in figure 9a. The DC battery is connected directly with the voltage converter to convert the high dc voltage into low voltages required to power the raspberry pi board, relay etc. The master device (NvidiaJetson Nano with Wifi dongle) interconnects the wireless router/internet enabled phone as shown in figure 9b. When tested, the slave device detects and captures the image of the maize insect pest such as Fall Armyworm (FAW), African Armyworm and Egyptian cotton leafworm and forwards the same to the master device. The master device uses pre-trained model to recognize and classify the insect pest (*Spodoptera* species) and finally sends to the cloud server for storage. The system performed excellently.

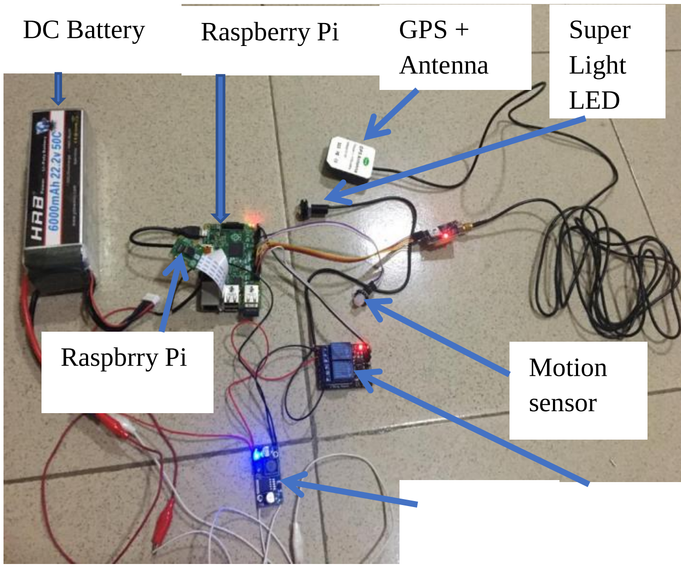

Figure 9a: Slave device connected and tested

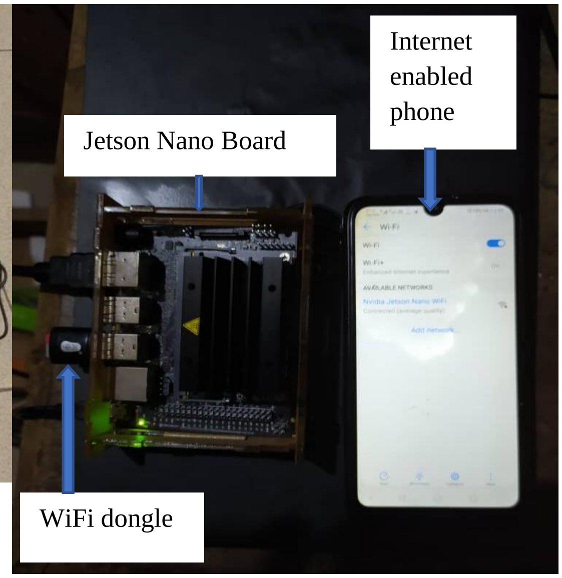

Figure 9b: Master Device with WiFi + phone

9.0 Maize Stem Borers' Mobile App

The Android mobile App is developed to assist farmers visualize these captured species remotely via Android mobile phone. The App shown in figure 10 was designed and programmed using Kotlin programming language. It can be downloaded via play store.

Figure 10: Home page of the Maize stemborer Android Mobile App

10.0 Conclusion

The emergence of ICT has brought about new technologies that can be used to design and build a smart system to aid farmers carry out such functions remotely without visiting their farm frequently. The manual process taken by farmers to monitor the presence of these insect pests in the maize farm is time consuming. Having seen the challenges faced by farmers in Nigeria such as inability to recognize the aggressive maize insect pests (*Spodoptera* species) in the farm and frequent visit to check-mate their maize crops from the attack of these insects, the IoT system was initiated to aid the farmers (both in the urban and rural areas) perform e-scouting remotely and recognize these maize insect pests without visiting the farm. The IoT Architecture designed would perform monitoring in the maize farm and alert farmers through Google Cloud platform and would drastically reduce the frequent visitation of the farmers in the farm to scout for these aggressive maize insect pests. The maize App initiated would also help the farmers to take appropriate control measures needed to control the influx of these species in the farm.

11.0 Recommendation

For further work, insecticide sprayers can be integrated into the IoT system and control buttons added in the maize mobile app to turn ON/OFF the sprayer. Solar energy system is also recommended as complimentary source of power to the IoT system.

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