Smart Crop Health Monitoring System

An AI-Powered Approach to Enhance Agricultural Productivity and Sustainability

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***Abstract*— Agriculture's productivity and sustainability heavily depend on crops' health. However, monitoring the health of crops can be a daunting task for farmers, as it requires continuous surveillance of crops and interpretation of data. In recent years, advances in technology have led to the development of smart crop health monitoring systems that leverage the power of Artificial Intelligence (AI) to automate the process of monitoring and analyzing crop health data. This paper presents an overview of a smart crop health monitoring system that uses AI algorithms to analyze the collected data and identify any anomalies or diseases affecting the crops. The proposed system can alert farmers in real-time about any crop health issues and provide them with actionable insights to take preventive measures. Additionally, the system can generate crop health reports to help farmers make informed decisions regarding crop management practices, such as irrigation, fertilization, and pesticide application.**

Keywords—crop health, Android Application, Machine learning, Rover, Disease detection;

I. INTRODUCTION

The agricultural sector provides a living for almost 58% of Indians. India is the second-largest producer of the two main staple foods in the world—rice and wheat. Several dry fruits, agriculturally based textile raw materials, roots, tuber crops, pulses, coconut, sugarcane, and a range of vegetables are among the goods produced in India that are currently rated second globally. At a time when the nation wants to increase agricultural production but also assure food security and nutrition for its expanding consumption needs, it is estimated that 15–25% of India's potential crop production is lost to pests, weeds, and diseases.

The objective behind developing the rover is to overcome the problem of crop destruction by pre-determining diseases in the crops and providing essential nutrients to the plants.

The development of the rover is done in two phases.

a) Maneuver the rover in the agriculture field

using an Android application that is interfaced by Bluetooth.

b) Detection and classification of the disease found in different crops.

1. Mobility

This rover is made up of an Arduino UNO, which is referred to as the rover's brain. With the aid of smartphones, a motor driver and DC motors are utilized to freely move the rover. A Bluetooth device serves as a communication channel between the Arduino UNO board on the smartphone and the motor driver. The design of the rover is based on the six-wheel framework that enables the rover to drive easily through the uneven terrain of the agricultural fields. This rover is using a 2200 mAh lithium polymer battery to provide 11.1 Volts of power.

a) Android Application

The Android application provides an interface between an Android device and an Arduino UNO. This code enables the Raspberry Pi4 to collect the image data necessary for disease diagnosis and also allows the user to give the commands to the rover which requires moving around the field. All rover operations are completely controlled by Android Application.

2. Disease Detection

The Raspberry Pi 4 and camera module will be used for plant disease detection. The camera module is used to capture a photo using the Android app and sends it to the Raspberry Pi, which classifies and detects the diseases before sending a message to the mobile device that is linked to the server. SVM (Support Vector Machine), is a machine learning classifier used for the classification of diseases in plants based on the symptoms in plants.

II. RELATED WORK

Bluetooth technology has risen substantially over the past few months. The technology is needed to address the demands of numerous needs nowadays with the help of Bluetooth-enabled remote-controlled robotic cars. Therefore,

with the aid of straightforward architecture, a robotically controlled car was designed and developed using open-source hardware. [1] For conducting an in-situ scientific study of goals that are distant by many meters to tens of kilometers, rocker bogies are crucial. Many wheels or legs are used in the complex mobility designs of today. The hostile Martian environment exposes them to mechanical breakdown. a four-wheeled rover with an effective suspension system was developed with a high degree of mobility that can travel through uneven terrain. [2] Low-level picture segmentation problems have been resolved using the well-known K-Means clustering method. Using a user-defined initial set of clusters that is updated with each iteration, initially identify the pixels that are primarily green in color. Following that, these mostly green pixels are muted based on predetermined threshold values computed with Otsu's method. The pixels on the edges of the infected cluster (object) and those with red, green, and blue values of zero were completely deleted as an additional step. The experimental findings show that the suggested method is a reliable method for the detection of plant leaves[3]. To distinguish between healthy and diseased leaves from the generated data sets, Random Forest Classifier is used. The phases of implementation included training and classification. To categorize the photos of sick and healthy leaves, the produced datasets of sick and healthy leaves are combined and trained using Random Forest. For feature extraction Histogram of an Oriented Gradient (HOG) is used. The model was trained using 160 images of papaya leaves and it achieves around 70% accuracy in the classification task[4]. Producing enough food to meet societal demand is now possible due to the growth of developed technologies. The food's and the crops' safety and security, however, remained unachieved. Climate change, a decline in pollinators, plant diseases, and other problems put farmers in a difficult position. To maximize the quality and segment the leaf samples, K-means clustering is first used. The K-means clustering response can be used to predict whether a leaf is infected or not at an early stage of operation. Second, the informative regions and features of the samples are extracted using various machine learning-based classifiers to predict the disease in the plants[5]. The creation of a tracking device that can be remotely controlled to carry out cadastral measurements. To obtain real-time kinematic (RTK) corrections via the internet, a Raspberry Pi Zero W module that receives position data from a VBOX 3iSR GNSS receiver and a particular modem was combined to create a Bluetooth-controlled rover. A cloud platform receives position and inertial data, allowing for remote monitoring and storage. Additionally, the power supply section was built to power the various acquisition section components, providing 2 hours of energy independence. A mobile application was created to control the rover and track its progress in real-time. [6]

III. PROPOSED METHODOLOGY

1) Data Collection

The collection of data is done by taking pictures of five crops that are wheat, rice, potato, corn, and tomato. This dataset consists of 24 classes. These classes consist of all diseased plant images and healthy plant images. As mentioned below, the classes of various plants are shown. The dataset contains 18,427 images which are further divided into 5 plant categories and 24 classes. The machine learning model classifies the diseased and non-diseased plants based on the features extracted from the image. The testing dataset contains 2,135 images which are used to test the performance of the developed system.

PLANTS	CLASSES
WHEAT	Wheat healthy Wheat stripe rust Wheat Septoria
RICE	Rice healthy Rice bacterial leaf blight Rice brown spot Rice leaf smut
POTATO	Potato healthy Potato late blight Potato early blight
CORN	Corn healthy Corn common rust Corn gray leaf spot Corn blight
TOMATO	Tomato healthy Tomato bacterial spot Tomato early blight Tomato late blight Tomato leaf mold Tomato spider mites Tomato Septoria leaf spot Tomato target spot Tomato mosaic virus Tomato yellow leaf curl virus

Table 1 Crops and their classes

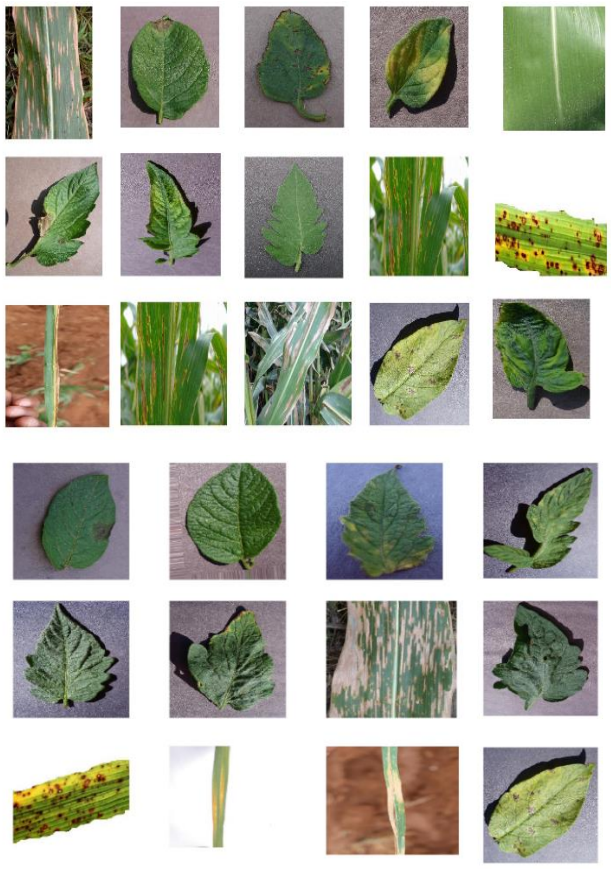

Figure 1. Sample images of Dataset

2) Core components

a) Raspberry Pi4

A compact single-board computer with 4GB of RAM, the Raspberry Pi 4 Model B is intended for several applications, including research, education, and hobby projects. It is the most capable and feature-rich Raspberry Pi to date, and it has vastly improved over earlier models. The quad-core ARM Cortex-A72 CPU found in the Raspberry Pi 4 offers considerable performance gains over earlier models. It operates at 1.5 GHz. It also has dual-band 802.11ac wireless connectivity, built-in Bluetooth 5.0, and Gigabit Ethernet, making it simple to connect to a range of networks and gadgets. More demanding programs, like data processing and machine learning, can operate without any issues thanks to the 4GB of RAM. Additionally, it has two micro-HDMI ports that can support two 4K displays at a frame rate of 60. The board contains several ports, including a USB-C port for power, two USB 3.0 ports, two USB 2.0 ports, and two USB 2.0 ports. Additionally, it has an audio jack for audio output and a microSD card slot for storage. It also features GPIO pins for attaching to external devices.

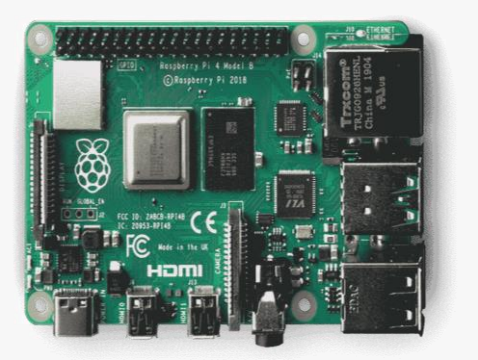

Figure 2. Raspberry Pi4

b) Motor Driver (L298N)

Robotics and mechatronics frequently use the twin H-bridge motor driver integrated circuit (IC) known as the L298N. Stepper motors and DC motors' direction and speed are intended to be controlled. With a maximum current of 2A per channel and a peak current of up to 3A per channel, the L298N can drive up to two motors concurrently. Pulse width modulation (PWM) signals can be used to control it, and it is compatible with several microcontrollers, including Arduino and Raspberry Pi. Additionally, the IC has integrated protection circuits for thermal shutdown, overvoltage defense, and under-voltage lockout. This guarantees that in the event of a problem, the L298N and the linked motors are protected from harm. The L298N is appropriate for a wide range of applications because of its broad operating voltage range of 5V to 46V. Additionally, it has an internal voltage regulator that can output 5V to power external devices. The L298N may control solenoids, relays, and other high-current devices in addition to controlling motors. Due to its adaptability, both professionals and hobbyists favor it.

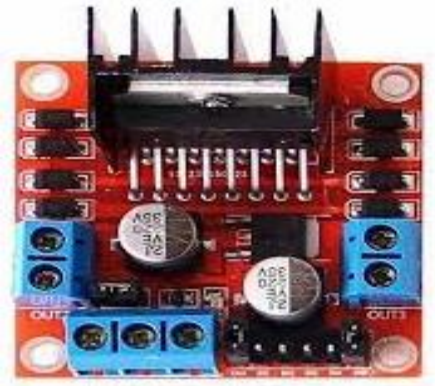

Figure 3. Motor Driver L298N

c) Arduino UNO

An open-source microcontroller board called Arduino Uno is made to be user-friendly and adaptable. It is a well-liked option for studies in robotics, automation, and other related topics. A set of digital and analog input/output pins on the board, which is based on the Atmel ATmega328P microcontroller, can be used to connect to different sensors, actuators, and other parts. The Arduino Uno's simplicity and ease of use are two of its key advantages. The Arduino Integrated Development Environment (IDE), a user-friendly software platform that makes it easier to write, upload, and debug code, can be used to program it. The Arduino Uno is not only straightforward to use but also quite adaptable. Shields, which are add-on boards that offer more functionality like Ethernet connectivity, wireless communication, or motor control, can be used to expand it. Due to its adaptability, it serves as a platform for a variety of research applications.

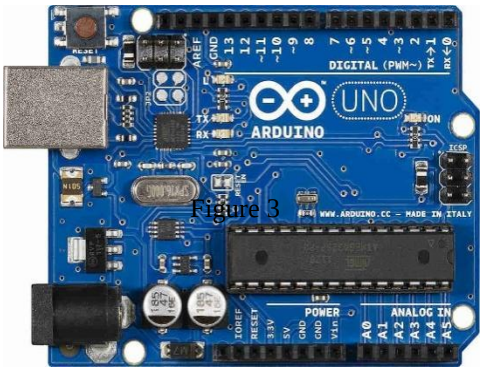

Figure 3

Figure 4. Arduino UNO

d) Bluetooth Module

A wireless communication module called the HC-05 Bluetooth can be utilized for a variety of tasks, including research projects. It is a compact module that offers wireless communication capabilities across close ranges and is simple to integrate into electronic circuits and devices. The majority of Bluetooth-enabled devices, including laptops, tablets, and smartphones, are compatible with the HC-05 module because it adheres to the Bluetooth 2.0 protocol. The HC-05 module's simplicity of usage is one of its main benefits. straightforward AT commands that are exchanged over a serial connection between the module and a microcontroller or computer make configuration straightforward. This makes it a well-liked option for researchers and amateurs who might not have a lot of background in wireless communication protocols. The HC-

05 module can be used with several microcontrollers and other electronic devices since it supports a range of baud rates. It is appropriate for a variety of applications, including data logging, remote control, and sensor monitoring because it can transport data at speeds of up to 2.1 Mbps.

Figure 5. Bluetooth Module HC-05

e) Camera Module

A compact camera module called the OV5647 is made for a range of electronic gadgets and research purposes. It's produced by Omni Vision and has a 5-megapixel image sensor in addition to several cutting-edge features that make it appropriate for a variety of research projects. The OV5647 camera module's tiny size, which makes it simple to integrate into electronic gadgets and other applications, is one of its primary benefits. Additionally, it has a built-in auto-focus mechanism that enables it to automatically change the image's focus. Additionally, the OV5647 module includes several sophisticated image processing capabilities, such as automatic gain control, automatic white balance, and noise reduction. It may therefore be used in a range of settings and lighting circumstances.I2C, SPI, and MIPI are just a few of the interfaces that the OV5647 module can use to connect to a variety of microcontrollers and other electrical devices. It can record video at resolutions as high as 1080p and capture photos up to 2592 x 1944 pixels.

Figure 6. Camera module OV5647

f) LiPo Battery

A common high-capacity rechargeable battery utilized in several electrical products and research purposes is the 11.1V 2200mAh lithium polymer battery. This particular form of lithium-ion battery is more versatile and can be produced in a range of shapes and sizes since it employs a polymer electrolyte rather than a liquid electrolyte. The battery can be used in a variety of electrical equipment because of its nominal voltage of 11.1V. Additionally, it has a capacity of 2200mAh, meaning it can supply a lot of power for a long time. Because of its high energy density, which allows it to store a lot of energy, lithium polymer batteries are well-known.

Figure 7. LiPo Battery

g) Motors

A compact, excellent motor with a 12-volt direct current power supply is the 150 RPM - 12V Centre Shaft DC Geared Motor. The motor has a gearbox installed, which increases its torque and allows it to deliver a maximum speed of 150 revolutions per minute (RPM). A circular wheel component with a 10 cm diameter and a 6 mm hole, called the Wheel - 10 cm Diameter - 6 mm Hole - Big size, is made for usage in a variety of machinery, robotics, and automation projects. The wheel is rather huge in size, measuring 10cm, or roughly 3.94 inches, in diameter. The wheel's big size enables it to travel swiftly and cover more ground with each turn, making it appropriate for uses requiring high speed or a wide range of movement. The wheel features a 6mm hole in the center that makes it simple to connect it to a motor shaft or other parts. It is simple to integrate the wheel into a variety of motor shafts since the hole is compatible with a wide range of motor shafts.

Figure 8. Motor and wheel

3) WORKING PRINCIPLE

The 6-wheeled rover, which is programmed in Arduino and powered by an 11.1 volts LiPo battery, can be easily controlled through an Android application that is connected to it via a Bluetooth device, and all the commands are provided through the same Android application. A Raspberry Pi 4 is used to detect diseases in plants. The process is straightforward: the user approaches the plant with the rover and issues a command via an Android device using an Android application. Upon pressing a button in the Android application, the Arduino board sends a serial command to the Raspberry Pi to execute a machine-learning sketch that can detect diseases. Once a disease is detected, a message is sent to the concerned person on WhatsApp.

a) Role of Raspberry Pi 4

The Raspberry Pi 4 is employed to detect diseases in crops and suggest appropriate solutions via WhatsApp. The model is trained using the SVM algorithm, which involves the utilization of a vast dataset encompassing five crops, namely Potato, Tomato, Rice, Wheat, and Corn, along with their corresponding diseases. Upon completion of training, the machine learning model is tested and saved as a sketch. When a serial command is issued to the sketch by the Arduino board, supplied by the Android application, the attached camera on the Raspberry Pi captures an image of the crop, which is then processed by the program. The model performs a classification task on the image to detect any potential diseases or to confirm whether the plant is healthy or not. Based on the result obtained, a message is sent accordingly. The message is provided in both languages Hindi and English.

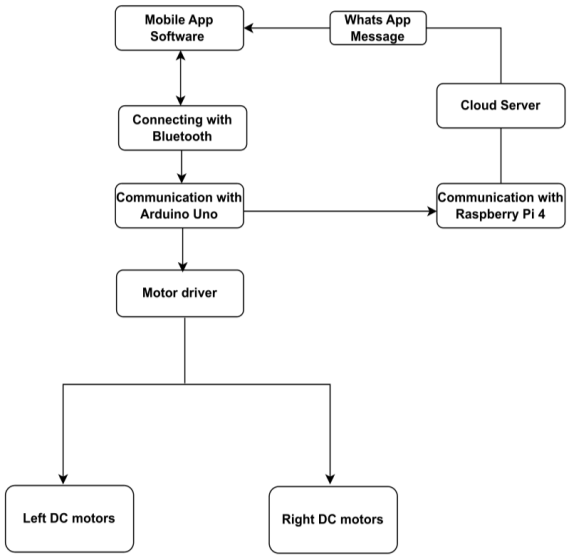

Figure 9. Working with Raspberry Pi

b) Arduino Board

The Arduino board is responsible for the mobility of the rover. The L298N Motor driver and HC-05 Bluetooth module are controlled by the Arduino board. All 6 motors are connected to the motor driver and the motor driver is connected to the Arduino through a digital pin. The working of the three components is very simple as illustrated in Figure 10. The Bluetooth Module sends commands to the Arduino and Arduino sends commands to the motor driver through which motors move according to the command.

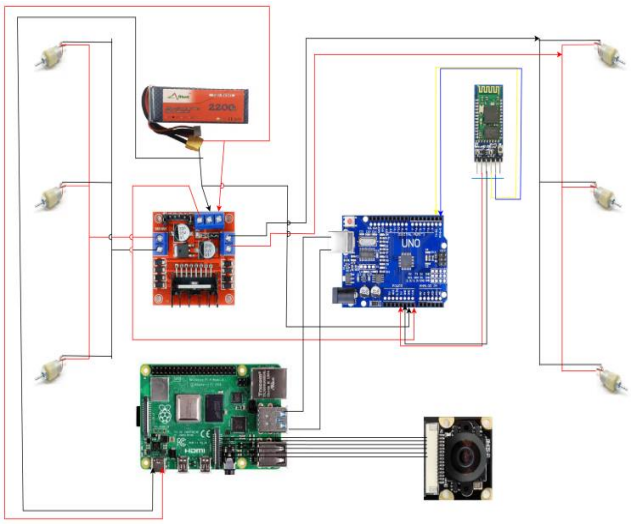

Figure 10. Circuit diagram

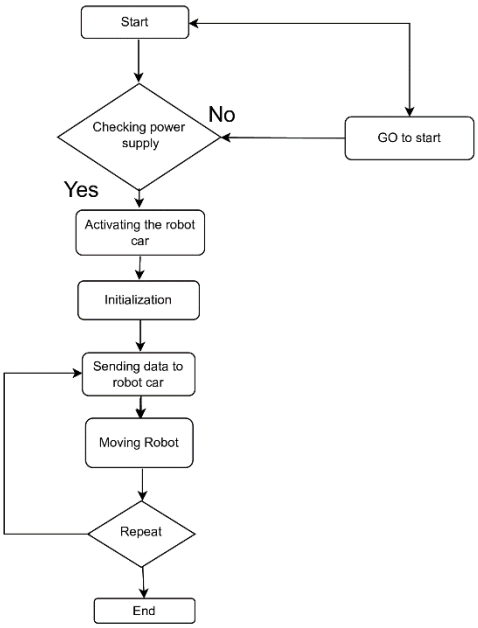

Figure 11. Process Check-up

IV. EXPERIMENTATION AND RESULTS

To evaluate the performance of the developed rover, we conducted experiments in a real-world scenario. The rover was deployed in a field of tomato plants infected with three different types of diseases: Early Blight, Late Blight, and Leaf Spot. The rover collected images of the infected plants, and the images were processed using our AI-based algorithm. Thus, the other plants are seasonal crops they also have been tested by using the testing dataset. After the model receives the image, it categorizes it and uses a sample image to identify the ailment. The testing dataset of five plant categories is used to test the other plants because only tomato plants were accessible at the time of the testing. The results of our experiments show that our developed rover is capable of accurately detecting the presence of diseases on plant leaves along with it sends a message to the user on WhatsApp about the health status of a plant and also suggests possible remedies to cure the disease (Figure 13) otherwise a

congratulations message is sent to the concerned person if the plant is disease free. The architecture of the developed rover is shown in Figure 12.

Figure 12. Structure of rover

Figure 13. Screenshot of the message sent by Raspberry Pi

V CONCLUSION AND FUTURE SCOPE

Various subsystems were integrated to construct a fully functional rover to solve the problem faced by farmers all over the globe. The monitoring of plant health in huge agricultural fields can be time-consuming well as needs human effort. To overcome the certain problem and save human effort which can be diverted for better purposes. This system successfully provides the solution for the affected crops by sending WhatsApp messages to the person, which identifies the disease as well as provides several possible solutions to cure the disease from the present stage. The operation of the rover in the agriculture field is also tested and can tackle pretty rugged surfaces.

In the future this system could incorporate a different camera for navigational purposes, allowing it to move independently and do the necessary tasks. The process of farming could also be made simpler in the future by the introduction of features like plowing and seed sowing. The bot can also be changed so that it can recognize diseases in a wider variety of plant species. Additionally, weeds can be removed automatically utilizing cutters and blades, saving the farmers from having to do it by hand.

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