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Crop Disease Detection Using Machine Learning Techniques

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Abstract: *The proposed project introduces an innovative plant disease detection, harnessing the power of a Raspberry Pi, advanced imaging technology, and Realtime SMS alerts to revolutionize agricultural practices. Designed to navigate fields independently, this camera captures detailed images of plant leaves and employs sophisticated image processing algorithms to identify early signs of diseases, including fungal infections, bacterial blight, and nutrient deficiencies. When a potential disease is detected, the system sends instant SMS notifications to farmers, enabling immediate action to mitigate crop loss. Central to the design is the Raspberry Pi microcontroller, and runs the detection algorithms. The high-resolution camera module plays a crucial role in ensuring accurate diagnosis, while the integrated GSM module facilitates seamless communication. Utilizing cutting-edge machine learning techniques, this system achieves high accuracy in disease recognition, even in diverse agricultural settings. Field tests have showcased its effectiveness, delivered rapid alerts and enhanced decision-making for farmers. By empowering growers with timely insights and proactive disease management, this promotes sustainable farming practices but also paves the way for smarter, technology driven agriculture. Crop diseases pose a significant threat to global food security, causing substantial yield losses and economic damage. Early disease detection is crucial for effective crop management and disease control. This project proposes an automated crop disease detection system using Raspberry Pi and machine learning techniques.*

Keywords: *Crop Disease, GSM Module, Machine Learning, Raspberry Pi.*

1. INTRODUCTION

The rise of automation and technology in agriculture has led to the development of innovative solutions aimed at enhancing crop health and maximizing agricultural productivity. One such solution is the integration of smart robots for plant disease detection, which plays a vital role in safeguarding crops against harmful pathogens and pests. Traditional methods of detecting plant diseases are often labor intensive, time-consuming, and prone to human error. They usually rely on visual inspection by experts or agricultural extension workers, which can lead to delayed diagnoses and the unnecessary use of pesticides. In contrast, the advent of smart robotics combined with Raspberry Pi and GSM modules provides an intelligent and efficient alternative. In this system, the Raspberry Pi, a small yet powerful single-board computer, serves as the central processing unit. It works with a camera and image processing algorithms to capture and analyze images of plant leaves to detect signs of diseases such as blights, rusts, and fungal infections. The system can be configured with machine learning models or classical image processing techniques to identify and classify diseases based on visual symptoms. Once a disease is detected, the system uses a GSM module to send an SMS alert to the farmer's mobile phone, notifying them of the specific issue. This immediate feedback allows farmers to take swift action, such as applying the appropriate treatment or adjusting environmental conditions, even if they are not physically present in the field. The use of a GSM module is particularly beneficial in remote or rural areas where internet connectivity might be unavailable, providing a low-cost and reliable communication method. The integration of automation, image recognition, and wireless communication ensures that plant disease detection becomes faster, more accurate, and accessible. This system is expected to reduce the use of pesticides, promote sustainable farming practices, and minimize crop loss, ultimately contributing to more efficient and environmentally friendly agricultural practices. Additionally, the accessibility and affordability of the Raspberry Pi platform make this solution scalable for small scale farmers, helping them enhance crop health management without requiring large investments. Problem Statement: Plant diseases are a major concern in agriculture, contributing to substantial crop losses worldwide and threatening food security. These diseases, which can be caused by fungi, bacteria, viruses, and pests, can spread rapidly across fields, significantly affecting both yield and quality of crops. Early detection and management of plant diseases are crucial in preventing widespread damage. However, traditional methods of disease detection, such as visual inspection by farmers or agricultural experts, have several limitations. These methods are time-consuming, subjective, and prone to human error.

As a result, diseases are often not identified until they have already caused considerable damage, leading to a delay in taking corrective action. In many cases, delayed disease detection leads to the overuse of pesticides, as farmers apply chemicals preventively or in response to symptoms they fail to recognize early. This overuse of pesticides not only increases the financial burden on farmers but also harms the environment, contributing to soil degradation, water pollution, and reduced biodiversity. Furthermore, the reliance on chemicals can lead to the development of pesticide-resistant strains of pathogens, making future disease management even more challenging. The situation is particularly problematic for small-scale farmers in rural or remote areas, where access to expert knowledge, advanced diagnostic tools, and modern technologies is limited. These farmers often rely on outdated methods and lack the resources to adopt more efficient disease management strategies. Many remote agricultural regions also face issues with poor or no internet connectivity, which further hampers the ability to use modern, internet-based tools for disease detection and management. This gap in technological adoption not only limits the farmers' ability to detect diseases early but also leaves them vulnerable to crop failure and financial instability. Given these challenges, there is a growing need for an automated, affordable, and reliable solution to detect plant diseases at an early stage. Such a system should be capable of analyzing plant images to identify signs of disease, alerting farmers in real time, and providing recommendations for corrective action. Moreover, it should be accessible to small-scale farmers, particularly in rural areas, where advanced agricultural technologies are often out of reach. By leveraging affordable technologies such as Raspberry Pi and GSM modules, it is possible to create an intelligent system that can autonomously monitor crops, detect diseases, and communicate alerts via SMS, even in areas with limited or no internet connectivity. Such a solution would empower farmers to take timely actions, reduce their dependency on harmful pesticides, improve crop yields, and contribute to more sustainable farming practices, ultimately benefiting both farmers and the environment.

Aim and Objectives: The primary aim of this project is to develop a smart robotic system for plant disease detection that integrates affordable technologies, such as Raspberry Pi and GSM modules, to automate the process of identifying plant diseases and notifying farmers in real-time. By leveraging machine learning and image processing techniques, the system will be able to detect early signs of diseases on plant leaves, allowing for prompt intervention and reducing the need for excessive pesticide use. Additionally, the system will help increase agricultural productivity by enabling smallholder farmers, especially in remote areas, to access advanced disease detection tools at an affordable cost. The overall goal is to create a solution that improves the efficiency of disease management, promotes sustainable agricultural practices, and reduces economic losses due to plant diseases. Objectives: 1. Develop a Disease Detection Algorithm: To create an image processing-based algorithm running on Raspberry Pi that accurately identifies plant diseases by analyzing visual data from plant leaves. This algorithm will be capable of distinguishing between different types of diseases, such as fungal infections, bacterial blight, and viral diseases. Implement Autonomous Navigation: To design and implement an autonomous robot capable of navigating agricultural fields, capturing images of plant leaves for disease detection. The robot should be able to cover large areas of farmland with minimal human intervention, ensuring that disease detection can occur across the entire field. 3. Integrate GSM Communication for Alerts: To integrate a GSM module into the system, enabling real-time communication between the robot and the farmer. When a disease is detected, the system will send SMS alerts with detailed information about the disease, its symptoms, and recommended actions, even in areas with limited or no internet connectivity. By achieving these objectives, the project aims to revolutionize plant disease detection, making it faster, more accurate, and accessible to farmers, ultimately leading to healthier crops, higher yields, and more sustainable agricultural practices.

2. LITERATURE REVIEW

This paper discussed about an automated system for identifying and classifying different diseases of the contaminated plants is an emerging research area in precision agriculture. This paper describes the approach to prevent the crop from heavy loss by careful detection of diseases. The region of internet is leaf because most of the diseases occur in leaf only. Histogram equalization is used to pre-process the input image to increase the contrast in low contrast image, K-mean clustering algorithm which classifies objects. Disease in crop leaf are detected accurately using image processing technique it is used to analyse the disease which will be useful to farmers. This paper describes an image processing technique that identifies the visual symptoms of plant diseases using an analysis of colored images, work of software program that recognizes the color and shape of the leaf image. LABVIEW software was used to capture the image of plant RGB color model and MATLAB software is used to enable a recognition process to determine the plant disease through the leaf images. The color model respectively was used to reduce effect of illumination and distinguish between leaf colors efficiently and the resulting color pixels are clustered to obtain groups of color in the images. The proposed algorithm is tested on main five diseases on the plant they are Early Scorch, Cottony mold, Ashen Mold, Late scorch, Tiny Whiteness. Initially the RGB image is acquired then a color transformation structure for the acquired RGB leaf image is created. After that color value in RGB converted to the space specified in the color transformation structure. In the next step, the segmentation is done by using K-means clustering technique after that mostly green pixels are masked. Finally, the feature extracted was recognized through a pre-trained neural network. The result shows that the proposed system can successfully detect and classify the diseases with a precision between 83% and 94%. Existing system: The existing system for plant disease detection have primarily relied on traditional, manual, and semi-automated methods, which often face challenges in terms of efficiency, scalability, and real-time responsiveness. A common approach involves manual inspection, where farmers or agricultural experts visually examine plants for signs of diseases such as spots, discoloration, and wilting. This method is labor-intensive, time consuming, and prone to human error, especially when dealing with large areas or subtle disease symptoms. Another existing method uses image processing and computer vision to detect plant diseases, where cameras capture high-resolution images of plant leaves, and algorithms analyze these images to identify symptoms. While these systems offer some level of automation, they are often limited by the need for fixed equipment, meaning they are stationary and unable to move autonomously across large fields. Furthermore, these systems may not have the capability to send real-time alerts to farmers, which means that diseases can spread undetected for extended periods. Drones, which are sometimes used for aerial surveillance, can capture images over large areas, but their high cost, limited battery life, and the need for human intervention in flight operations and data analysis restrict their widespread use. In some cases, environmental sensors are employed to monitor conditions like humidity, temperature, and soil moisture, which may signal favorable conditions for disease development. However, these sensors do not directly detect diseases and only provide indirect clues about potential disease risks. Other systems rely on smart phone applications, where farmers take pictures of diseased plants and upload them to a cloud database for analysis, but these apps can suffer from inaccurate diagnoses and require a stable internet connection, which is not always available in rural or remote farming areas. The GSM module, commonly used in communication systems, is also sometimes integrated with sensors and devices to send alerts about environmental conditions, but it may not be used in conjunction with autonomous systems for real-time disease detection. Therefore, while these existing systems have their merits, they are limited by their reliance on manual inspection, fixed setups, or expensive technologies, and often lack real-time disease detection and alerts. Proposed System: The main purpose of proposed system is to detect the diseases of plant leaves by using feature extraction methods where features such as shape, color, and texture are taken into consideration. Convolutional neural network (CNN), a machine learning technique is used in classifying the plant leaves into healthy or diseased and if it is a diseased plant leaf, CNN will give the name of that particular disease. First the images of various leaves are acquired using high resolution camera so as to get the better results & efficiency. Then image processing techniques are applied to these images to extract useful features which will be required for further analysis.

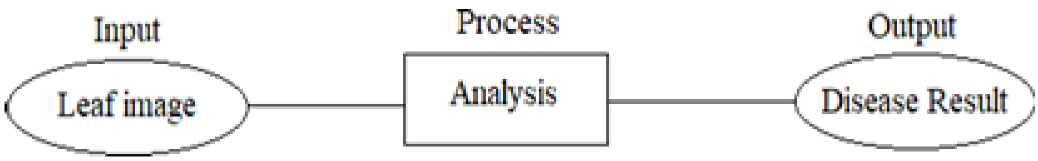

FIGURE 1. Proposed system

Use of estimators for automatic Initialization of cluster centres so there is no need of user input at the time of segmentation. The detection accuracy is enhanced with proposed algorithm. Proposed method is fully automatic while existing methods require user input to select the best segmentation of input image. It also provides environment friendly recovery measures of the identified disease. India is an agricultural country, where most of the population depends on agricultural products. So, the cultivation can be improved by technological support. Diseases may cause by pathogen in plant at any environmental condition. In most of the cases diseases are seen on the leaves of the plants, so the detection of disease plays an important role in successful cultivation of crops. There are lots of techniques to detect the different types of diseases in plants in its early stages.

Schematic Diagram

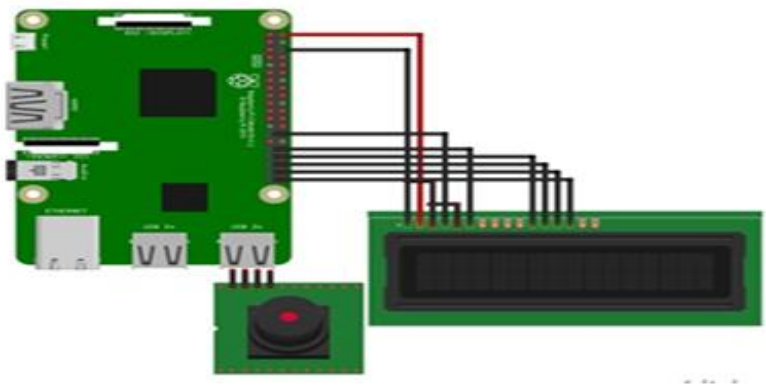

FIGURE 2. Schematic Diagram

Block Diagram

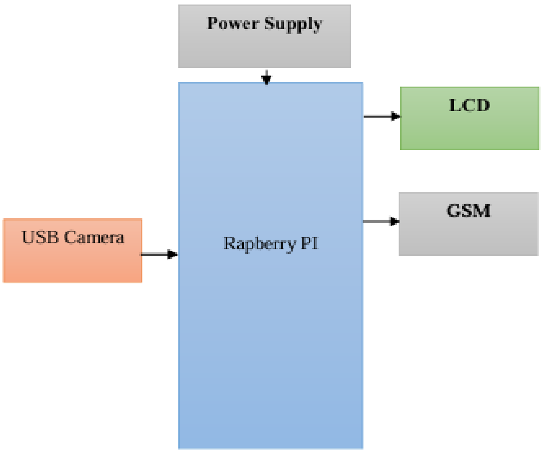

FIGURE 3. Block Diagram of Crop Disease Detection

Power Supply Unit: Provides regulated power to Raspberry Pi and other peripherals. It can be powered battery or solar panel for field deployment. Raspberry Pi: Acts as the brain of the system. Controls peripherals, processes data, and runs ML models for detection. Camera Module: Captures images of crop leaves. Connected to Raspberry Pi via CSI (Camera Serial Interface). Display/LCD: Results can be shown on an LCD screen or through a web/mobile app. The GSM module (like SIM800C) sends SMS alerts about plant diseases via UART to a Raspberry Pi. The Pi uses AT commands to configure the module for text messaging. When a disease is detected, a predefined message with the disease name is sent to the user's phone. This is useful in areas with unreliable internet, enabling real-time alerts without cloud services.

USB Camera Connection: The USB camera is used to capture images of plant leaves for disease detection. It is connected directly to the USB port of the Raspberry Pi. • The camera takes images, which are processed using image processing and machine learning algorithms (such as VGG16 or MobileNetV2). • The Raspberry Pi analyzes the images and detects whether the plant is affected by a disease. • Once the disease is detected, the result is displayed on the GUI and sent via the GSM module as an SMS notification. The USB camera plays a crucial role in real-time plant disease detection by capturing images that are processed through deep learning models to classify plant diseases.

Flowchart:

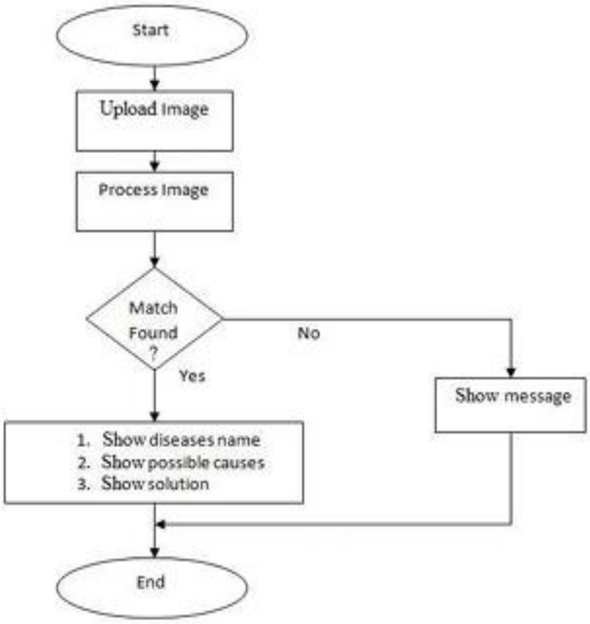

FIGURE 4. Flowchart of Crop Disease Detection

The system starts running on Raspberry Pi. Initialize Raspberry Pi & LCD Raspberry Pi and the connected LCD display are initialized. Hardware components like camera, display, and GPIO are prepared for use. Capture Image Using Webcam The webcam connected to the Raspberry Pi captures an image of the plant leaf. The image is passed for processing. Process Image Using Machine Learning Model The captured image is sent to the CNN-based machine learning model. The model analyzes leaf features (color, shape, texture) and classifies the image. Decision: Disease Detected? If no disease is detected: → The system saves the image and updates the LCD with “Healthy Plant” status. If disease is detected: → The system updates the LCD with “Disease Detected” message. Send Telegram Alert (If Diseased) If a disease is detected, a notification is sent to the user via Telegram. The alert includes the disease name and suggested remedy Wait 15 Seconds This prevents continuous processing and gives time for any updates.

3. HARDWARE COMPONENTS

Power Supply: The power supply section is the section which provide +5V for the components to work. IC LM7805 is used for providing a constant power of +5V. The ac voltage, typically 220V, is connected to a transformer, which steps down that ac voltage down to the level of the desired dc output. A diode rectifier then provides a full-wave rectified voltage that is initially filtered by a simple capacitor filter to produce a dc voltage. This resulting dc voltage usually has some ripple or ac voltage variation. A regulator circuit removes the ripples and also retains the same dc value even if the input dc voltage varies, or the load connected to the output dc voltage changes. This voltage regulation is usually obtained using one of the popular voltage regulator IC units.

FIGURE 5. Power Supply

Camera Module: The Zebronics Zeb-Crystal Pro is a USB-powered web camera designed for clear video communication. It features a 3P high-quality lens and a CMOS image sensor, delivering video resolutions of up to 640 x 480 pixels at 30 frames per second. The webcam includes a built-in microphone for seamless audio during calls and offers night vision capabilities for low-light conditions. Its clip-on design allows for easy mounting on monitors or laptops. The device connects via USB, with a cable length of 1.2 meters. fig.3.3.1 shows USB web camera Specifications: Interface: USB Image Sensor: CMOS Lens: 3P high-quality lens Video Resolution: 640 x 480 pixels at 30 FPS Cable Length: 1.2 meters. Dimensions: Approximately 40.5 x 63.5 x 70.5 mm Weight: Approximately 70 grams Features: High-Quality 3P Lens: Equipped with a 3P high-quality lens, the webcam delivers clear video output. Video Resolution: Supports a video resolution of 640 x 480 pixels at 30 frames per second, suitable for standard video calls. Built-in Microphone: Features an integrated microphone to capture audio during video calls, eliminating the need for an external mic. Night Vision: Includes night vision capabilities, allowing for better visibility in low light conditions. Manual LED Switch: Comes with a manual switch to control the LED lights, providing flexibility based on lighting needs. Clip-On Design: Designed with a clip-on mechanism for easy attachment to monitors, laptops, or other surfaces. SB Interface: Utilizes a USB interface for power and connectivity, ensuring compatibility with various devices.

FIGURE 6. USB Web Camera

Liquid Crystal Display (LCD): LCD (Liquid Crystal Display) screen is an electronic display module and find a wide range of applications. A 16x2 LCD display is very basic module and is very commonly used in various devices and circuits. These modules are preferred over seven segments and other multi segment LEDs. The reasons being: LCDs are economical; easily programmable; have no limitation of displaying special & even custom characters (unlike in seven segments), animations and so on.fig.3.4.1 shows the 16x2LCD A 16x2 LCD means it can display 16 characters per line and there are 2 such lines. In this LCD each character is displayed in 5x7 pixel matrix. This LCD has two registers, namely, Command and Data. The command register stores the command instructions given to the LCD. A command is an instruction given to LCD to do a predefined task like initializing it, clearing its screen, setting the cursor position, controlling display etc. The data register stores the data to be displayed on the LCD. The data is the ASCII value of the character to be displayed on the LCD.

FIGURE 7. 16X2 LCD

Data/Signals/Execution of LCD:

LCD accepts two types of signals, one is data, and another is control. These signals are recognized by the LCD module from status of the RS pin. Now data can be read also from the LCD display, by pulling the R/W pin high. As soon as the E pin is pulsed, LCD display reads data at the falling edge of the pulse and executes it, same for the case of transmission. LCD display takes a time of 39-43µS to place a character or execute a command. Except for clearing display and to seek cursor to home position it takes 1.53ms to 1.64ms. Any attempt to send any data before this interval may lead to failure to read data or execution of the current data in some devices. Some devices compensate the speed by storing the incoming data to some temporary registers. Instruction Register (IR) and Data Register (DR) There are two 8-bit registers in HD44780 controller Instruction and Data register. Instruction register corresponds to the register where you send commands to LCD e.g. LCD shift command, LCD clear, LCD address etc. and Data register is used for storing data which is to be displayed on LCD. when send the enable signal of the LCD is asserted, the data on the pins is latched in to the data register and data is then moved automatically to the DDRAM and hence is displayed on the LCD. Data Register is not only used for sending data to DDRAM but also for CGRAM, the address where you want to send the data, is decided by the instruction you send to LCD. We will discuss more on LCD instruction set further in this tutorial. Commands and Instruction set only the instruction registers (IR) and the data register (DR) of the LCD can be controlled by the MCU. Before starting the internal operation of the LCD, control information is temporarily stored into these registers to allow interfacing with various MCUs, which operate at different speeds, or various peripheral control devices. The internal operation of the LCD is determined by signals sent from the MCU. These signals, which include register selection signal (RS), read/write signal (R/W), and the data bus (DB0 to DB7), make up the LCD instructions (Table 3). There are four categories of instructions that Designate LCD functions, such as display format, data length, etc. Set internal RAM addresses, Perform data transfer with internal RAM, Perform miscellaneous functions.

Software Specification: Machine Learning: Machine learning (ML) is the study of algorithms and mathematical models that computer systems use to progressively improve their performance on a specific task. Machine learning algorithms build a mathematical model of sample data, known as "training data", in order to make predictions or decisions without being explicitly programmed to perform the task. Machine learning is closely related to computational statistics, which focuses on making predictions using computers. The study of mathematical optimization delivers methods, theory and application domains to the field of machine learning. Data mining is a field of study within machine learning, and focuses on exploratory data analysis through unsupervised learning. Machine learning tasks are classified into several broad categories. In supervised learning, the algorithm builds a mathematical model of a set of data that contains both the inputs and the desired outputs. For example, if the task were determining whether an image contained a certain object, the training data for a supervised learning algorithm would include images with and without that object (the input), and each image would have a label (the output) designating whether it contained the object. In special cases, the input may be only partially available, or restricted to special feedback. Semi- supervised learning algorithms develop mathematical models from incomplete training data, where portions of the sample inputs are missing the desired output. Plant disease identification by visual way is more laborious task and at the same time, less accurate and can be done only in limited areas. Whereas if automatic detection technique is used it will take less efforts, less time and become more accurate. In plants, some general diseases seen are brown and yellow spots, early and late scorch, and others are fungal, viral and bacterial diseases. Image processing is used for measuring affected area of disease and to determine the difference in the colour of the affected area.

4. RESULTS

We have finally reached our goal. We have to implement the hardware as all equipment is at our hands. So, in a nutshell the whole procedure is as follows Procedure 1. Initialization Webcam and LCD 2. Checking for disease 3. Trigger the

LCD for the disease information 4. Stop Result Finally, we have successfully implemented the circuit. It can be easily implemented in elections and remote and local services.

5. ADVANTAGES, DISADVANTAGES & APPLICATIONS

Advantages: Cost-Effective: Reduced Labor Costs: Automating disease detection reduces the need for manual inspection, saving labor costs. Real-time Monitoring: Continuous Monitoring: Raspberry Pi enables continuous monitoring of crops, allowing for early detection of diseases. Increased Accuracy: Machine Learning Algorithms: Raspberry Pi can run machine learning algorithms that improve disease detection accuracy. Flexibility and Scalability: Scalability: Raspberry Pi can be easily scaled up or down depending on the specific needs of the farm or agricultural setting. Ease of Use: User-Friendly Interface: Raspberry Pi can be connected to a user-friendly interface, making it easy for farmers to use.

Disadvantages: Environmental Factors 1. Lighting Conditions: Raspberry Pi's camera may be affected by varying lighting conditions, such as sunlight, shade, or artificial lighting. 2. Temperature and Humidity: Raspberry Pi may be sensitive to extreme temperatures and humidity levels, which can affect its performance. 3. Weather Conditions: Raspberry Pi may be affected by weather conditions, such as rain, wind, or extreme temperatures.

Applications: Precision Agriculture: 1. Crop Monitoring: Raspberry Pi can be used to monitor crop health and detect diseases in real-time. 2. Soil Health Monitoring: Raspberry Pi can be used to monitor soil health and detect diseases that may affect soil quality. Smart Farming: 3. Automated Farming: Raspberry Pi can be used to automate farming tasks, such as crop monitoring and disease detection. 4. Farm-to-Table: Raspberry Pi can be used to track crop health and quality from farm to table. Commercial Applications: 5. Crop Insurance: Raspberry Pi can be used to develop crop insurance programs that provide financial protection to farmers in case of crop disease outbreaks. 6. Food Safety: Raspberry Pi can be used to detect diseases that may affect food safety and quality.

6. CONCLUSION & FUTURE SCOPE

There are number of ways by which we can detect disease of plants and suggest remedies for them. Each has some pros as well as limitations. On one hand visual analysis is least expensive and simple method, it is not as efficient and reliable. Image processing is a technique which is most spoken for very high accuracy and least time consumption are major advantages offered. Recognizing the disease accurately and efficiently is mainly the purpose of the proposed approach. The experimental results indicate that the proposed approach is a valuable approach, which can significantly support an accurate detection of leaf diseases in a little computational effort. Alongside the supply of cultivation tools, the farmers also need access to accurate information that they can use for efficient crop management and there is no better way than providing them a service that they can use through the software. 7.2 Future scope: To improve recognition rate of final classification process hybrid algorithms like Artificial Neural Network, Bayes classifier, Fuzzy Logic can also be used. Mobile application can be developed which is handy and easy to use. An extension of this work will focus on automatically estimating the severity of the detected disease. As future enhancement of the project is to develop the open multimedia (Audio/Video) about the diseases and their solution automatically once the disease is detected.

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