AI-Enabled Automated Farming Car-Bot for Smart Irrigation and Plant Disease Management

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Publication Date: 2026/07/23

Abstract: This article talks about an AI-driven automated vehicle farming bot that could be used for smart irrigation and controlling plant diseases. The project uses the Internet of Things, image processing, and machine learning to make crops more productive, use resources more efficiently, and be more sustainable. We use an ESP32 microcontroller with an ESP32 CAM module to take real pictures of plant leaves in the field to find diseases. After that, the pictures are looked at for plant diseases and other problems that might happen early in the infection. A machine-learning-based prediction model is used to correctly classify diseases. The system not only finds diseases, but it also uses sensors to keep an eye on the soil moisture level all the time, which makes the irrigation process easier. The controller figures out how much water is needed to keep the soil in the best condition for plant growth and to avoid both underwatering and watering stress. The system also lets farmers know about the health of their plants and the status of their irrigation in real time through cloud-based communication. So, this system's combination of automated disease detection and smart water management reduces the need for manual labour, makes better use of water, reduces crop loss, and promotes sustainable precision farming.

Keywords: *Smart Agriculture, Internet of Things, Plant Disease Detection, Smart Irrigation, Image Processing, Machine Learning, ESP32 Microcontroller.*

How to Cite: N. Muthukumaran (2026) AI-Enabled Automated Farming Car-Bot for Smart Irrigation and Plant Disease Management. *International Journal of Innovative Science and Research Technology*, 11(7), 819-826. https://doi.org/10.38124/ijisrt/26jul051

I. INTRODUCTION

The world's population is growing quickly, and we need more food, which is making it hard for us to farm the way we usually do. These days, farming has problems like watering crops the old-fashioned way, not catching sick plants soon enough, using too much water, and needing too many workers. This costs too much, hurts the planet, and makes us grow less [1]. To grow more food while using fewer resources, farming needs to get smarter with technology and data. Small computers, the Internet of Things (IoT) [3], and AI are making it possible to watch farms in real time and make choices on their own. With sensors and networks, IoT systems let us check the health of the dirt, air, and plants all the time. [3]. But many systems only keep an eye on the environment or control watering. They do not fix the big problem of not being able to see sick plants early enough, which costs us a lot of crops. When plants get sick, we get less food and it is not as good. Farmers usually must walk around and look for sick plants, which takes time, costs money, and is not always right, especially on big farms. If we do not find diseases quickly, they can spread quickly, which means we need more bug killers and lose more money. So, today's smart farms need to use cameras and computer learning to find diseases on their own. [8]. Using water, the wrong way is a big problem, especially when there is not much of it. Plants can get stressed and grow less if they do not get enough water. Too much water can damage roots and make mold grow. Old watering systems waste water because they cannot change to fit what you really need. Smart watering systems can check the dirt with sensors and only give the plants the right amount of water.

This paper is about a car-bot that uses AI to find sick plants and water crops in a smart way. It has a little computer and a camera that can take pictures of leaves in the field. Then, it uses computer tricks to look for signs of illness and AI to figure out what is wrong early on. The system also controls the flow of water to keep it just right, while dirt sensors check how wet the ground is. The system also uses the cloud to send alerts and updates to farmers over the Internet. This lets them keep an eye on things from a distance and act quickly when they need to. The computer inside is powerful, can connect to the Internet, and works well with the camera and sensors. We can make farming better and use fewer resources by finding diseases and watering plants smartly in one small machine. A small, smart farming system that combines disease detection with computer learning and automatic watering is what is new here. Because we can identify diseases early, farming becomes more environmentally friendly by using less pesticides and wasting less water. Additionally, the car-bot is mobile, making it suitable for both large and small farms. AI, IoT, and automation are good ways to make our food systems sustainable and waste-free, and farming that uses technology to be more precise is becoming more important. This paper demonstrates how computers can solve farming issues and pave the way for future, more intelligent farming.

II. RELATED WORK

This section examines the current state of smart farming systems. I am focusing on how people are using IoT to monitor things, how machine learning and image processing can identify plant diseases, and clever ways to regulate watering. I'll highlight the shortcomings of the current approaches and the need for an all-in-one, self-sufficient farming solution.

➢ *IoT Smart Farming and Monitoring*

Utilizing the Internet of Things in agriculture allows us to monitor temperature, humidity, and soil moisture levels in real time [2]. Numerous researchers have developed Internet of Things (IoT) farming systems that water fields using small computers and wireless technology, allowing you to view the data from any location [3]. Using apps or online dashboards, farmers can monitor their crops, make better decisions, and reduce manual labour. Soil sensors are used by many modern smart watering systems to determine when to water. They do not always know what each crop needs or how the weather is going, but they are still preferable to just watering whenever. Furthermore, the majority of IoT systems only manage watering; they do not monitor plant health, which somewhat restricts how much they can increase crop growth. Additionally, some IoT configurations rely too heavily on cloud computing, which can cause delays, consume power, and require constant internet access. That is not the best option for large or distant fields. Smart IoT setups that can monitor events and make decisions in the field are what we need.

➢ *Image Tricks and Machine Learning to Find Sick Plants*

Image intelligence has been used to automatically identify plant diseases, which is far superior to using the human eye. To identify problem areas, early attempts examined photos of leaves, analysing their colours, shapes, and textures [4]. To zoom in on strange areas, they used techniques like cutting out portions of the image, identifying edges, and verifying colour levels. As machine learning improved, people began to use tools like support machines, fake brains, and nearest neighbours (K-means Clustering) to identify diseases more accurately [5]. To identify what is what, these must be trained with tagged images and fed information. They are more accurate than the previous methods, but poor lighting, disorganized backgrounds, and low-quality images can cause problems. Recent research is attempting to classify plant diseases using deep learning, which is achieving excellent results by learning features independently. Deep learning is difficult to run on small, battery-powered devices because it requires a lot of computer power and data [6]. This indicates that many disease-spotting systems rely on cloud computing, which slows things down. Lightweight image processing and machine learning that can function well on simple setups are therefore crucial.

➢ *Smart Watering and All-in-One Farming Systems*

By adjusting their watering schedules according to soil conditions and cloud cover, smart watering systems aim to use precisely the right amount of water [7]. Some researchers have developed watering systems that operate in a loop, adjusting the flow of pumps or valves based on the wetness of the soil. These prevent plants from being stressed or drowned, which conserves water and promotes growth. Despite these advancements, the majority of smart watering systems still do not communicate with plant health monitors. Combining disease detection and watering control in a single setup has not required much effort. Additionally, many systems use stationary sensors, which means they cannot see everything, and large fields require a large number of them. Robotic platforms that can cover more ground and collect data more easily have been introduced for farm watching in recent studies. However, these can be expensive and confusing. A low-cost, portable, and compact smart farming system is obviously needed. From a single platform, it can detect plant diseases, water intelligently, and communicate via the Internet of Things. By combining image intelligence, machine learning disease detection, IoT smart watering, and a mobile monitoring platform, the suggested AI farming car-bot achieves this. For precise farming tasks, this combination offers live viewing, fast reaction times, adequate field coverage, and growth space.

III. SYSTEM DESIGN AND HARDWARE

We have created an automated farming robot driven by AI. It's constructed so that we can easily add to or modify it. It uses wireless, sensors, and a computer to monitor plant diseases and manage watering without wasting any resources. There are four components to the system:

- *Sensing:* This section collects information.
- *Processing*: This step determines the meaning of data.
- *Decision Making*: This section makes decisions.
- *Communication*: This section exchanges information.

This method of assembly gives it flexibility, which ensures that every component functions as it should . For farming, this puts things right.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26jul051

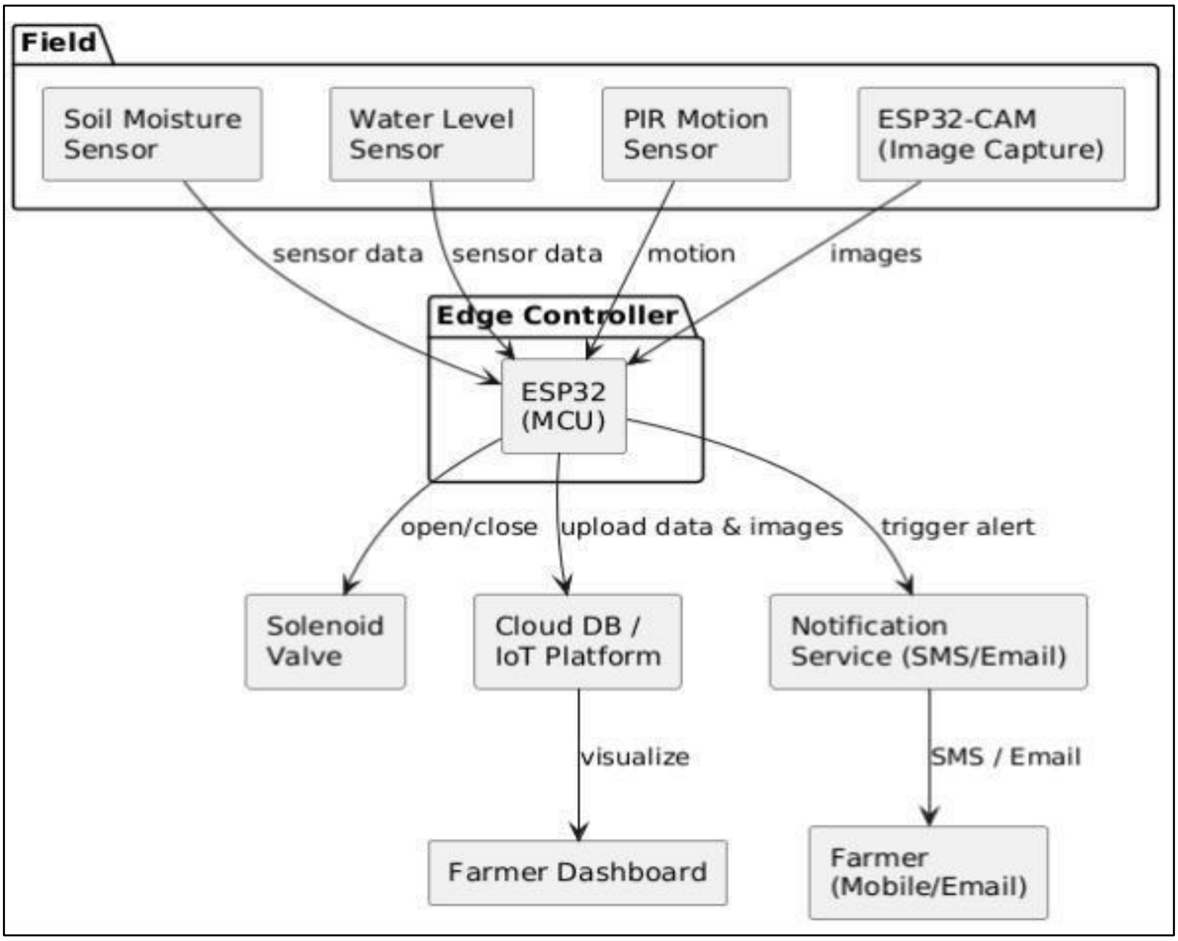

Fig 1 Block Diagram

➤ *How it's All Put Together*

An ESP32 microcontroller serves as the system's brain. It is connected to a motor driver, a valve, a camera, and a soil moisture sensor. The soil sensor measures the amount of moisture in the soil while the camera captures images of plant leaves. After analysing this data, the ESP32 uses Wi-Fi to transmit some of it to the cloud. In this manner, we can monitor everything and receive notifications if something is amiss.[12] The robot's mobility allows it to capture images of plants throughout the field. This implies that it can cover a large area, be it a large farm or a small garden. We've developed a clever method to monitor crops by using photos to identify diseases and automatically watering plants.

➤ *Why we Picked these Parts*

How well it functions, how much it costs, and how much power it uses are all greatly influenced by the materials we use inside. We chose the ESP32 because it has two processors, Bluetooth, Wi-Fi, low power consumption, and enough pins to connect everything. Because it can handle images and perform machine learning, it is superior to older controllers. We take pictures with the ESP32 CAM. Its camera is capable of taking crisp images, making it ideal for diagnosing illnesses. It's perfect for observing what's going on on the farm because it's compact and compatible with the ESP32. We use a sensor that measures the amount of water in the soil to determine how wet it is. These readings are converted into numbers by the ESP32. It automatically irrigates the plants if the soil is too dry. The water is managed by a valve. To ensure security, a relay or motor driver connects it to the ESP32. Additionally, the motor driver guides the robot along a predetermined path across the field.

➤ *How we Power it*

For mobility, the system is powered by a battery. To ensure that components like the ESP32 and the camera have consistent power, we employ special circuits. By only turning on components when necessary, we conserve energy. We don't want to constantly need to charge it, so this is crucial.

➤ *How it Gathers and Uses Data*

Regularly or when the robot is in specific locations, the camera captures images of leaves. The soil sensor measures the moisture at the same time. The images are sent to the disease-checking section after being somewhat cleaned up. A predetermined level of soil moisture is compared by the ESP32. It activates the water valve if it's too low. It stops watering to prevent giving too much when the soil is sufficiently moist.

➤ *Putting it Together and Making it Reliable*

To enable them to withstand being outside, all the components are assembled. We shield them from dust, water, and temperature fluctuations. We can upgrade or replace components without disrupting the system as a whole because it is constructed in parts. It functions well without much assistance from us because the sensors, computer, and water system all cooperate seamlessly. It's a good beginning for a sophisticated farming setup because it can move around, sense things in real time, and run everything.

IV. IMAGE PROCESSING AND MACHINE LEARNING BASED DISEASE DETECTION

Early detection of sick plants is crucial for modern farming. Plant diseases affect your ability to grow, the quality of your crops, and the overall performance of your farm. If you identify the diseases early on, you can take immediate action, lose fewer plants, and use fewer harmful insecticides. However, the traditional method of disease detection is labour-intensive, slow, and prone to error [8]. Having large fields to monitor can be quite annoying. Thus, this system immediately detects and labels plant diseases using cameras and computer intelligence.

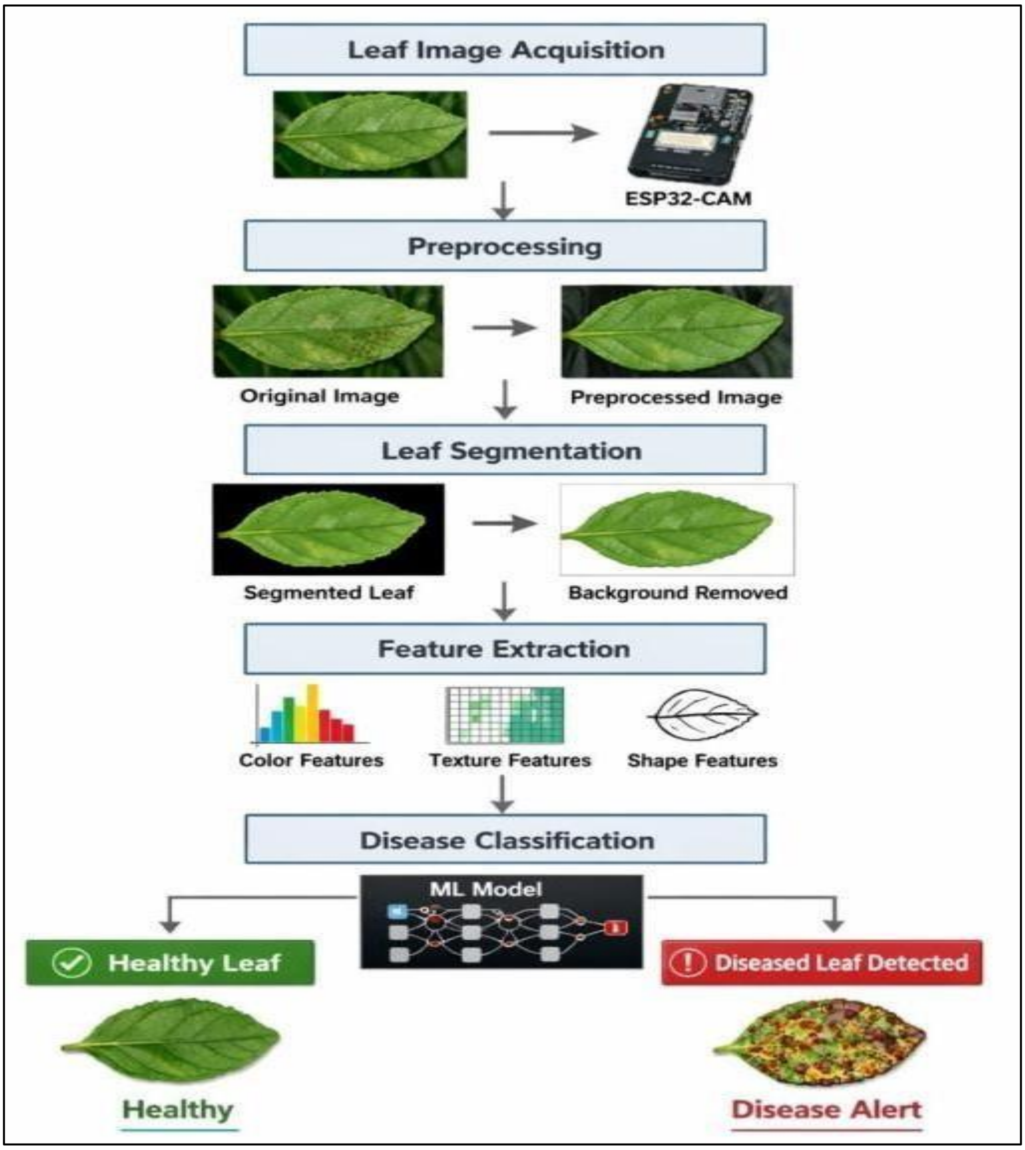

Fig 2 Image Processing and Machine Learning Based Disease Detection

This system makes use of a self-driving farm robot's camera. It captures images of the plant leaves as it travels across the field. You can inspect a large number of plants without investing a lot of money in cameras by using a robot equipped with a camera. Additionally, the camera is power-efficient and compatible with small computers, making it ideal for field use.

The system cleans the photos after they are taken to ensure they are sufficient to identify illnesses. It makes the colours stand out, adjusts the size, and eliminates fuzziness [13]. This is significant because sunlight, shadows, and background clutter can make photos taken outside appear strange. The system functions better when all the images have the same appearance. The system then identifies only the leaf in the image. This makes it easier for it to spot any odd hues or patches on the leaf while ignoring the background. It is useful for identifying things like spots and strange colours that indicate the plant is sick because it employs some clever tricks to group colours together.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26jul051

The system then converts the leaf image into a series of numbers. These numbers provide the computer with information about the image's colours, textures, and shapes. These figures serve as hints to distinguish between healthy and sick leaves. The computer can identify diseases quite accurately if the clues are good. These figures are then fed into a computer program that has been trained to determine whether a plant is ill. The program examines several prelabelled images to determine what healthy and sick leaves look like. When it has gained enough knowledge, it can determine whether the plant is ill by analysing fresh images captured by the camera. The interesting thing is that the computer gets better at identifying illnesses as it sees more. The system alerts the farmer when it discovers a sick plant.

Instead of sending everything to a big computer somewhere far away, this system does most of the work right there in the field. This makes it faster and means it can still work even if the internet is down. This is good because farms often do not have great internet. When the system finds a sick plant, it sends a heads-up to the farmer.

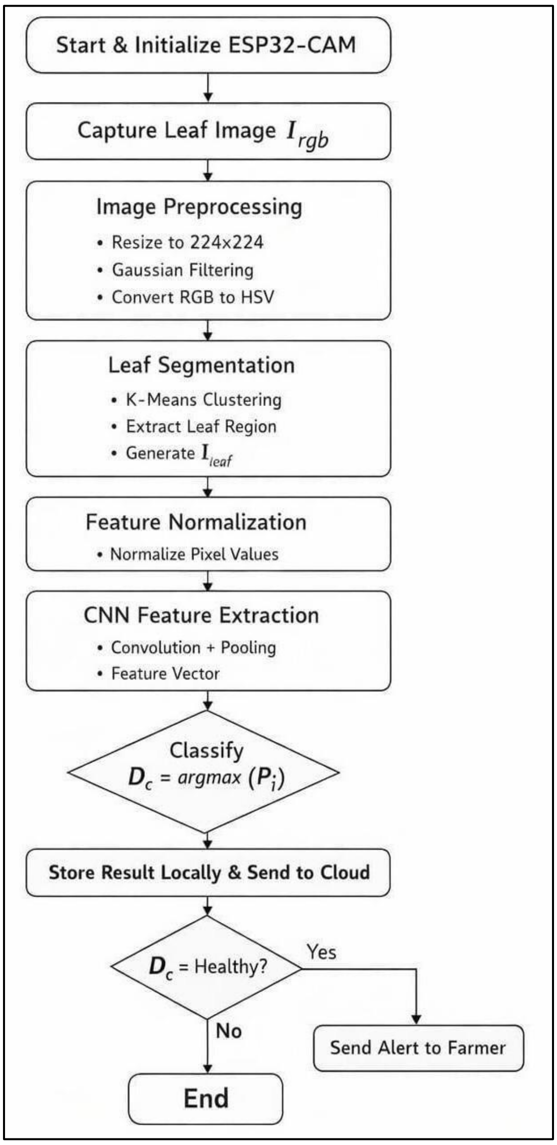

Fig 3 CNN -Based Disease Detection Algorithm

From a technical perspective, Fig. 3 illustrates that the system is designed to be precise without being overly power-hungry. It can operate for a long time without someone interfering because the computer tricks it employs are fast and require little power. Additionally, because computers are quick, they can identify illnesses practically immediately after a picture is taken. The system also addresses the fact that soil and weather conditions can alter a plant's appearance. In order to avoid being tricked by sunlight or unusual weather, it cleans up the images and employs cunning techniques to locate the crucial information. It becomes more adept at overlooking these distinctions as it gains knowledge [11].

It is far better to use a robot equipped with a camera than to simply leave a camera in one location. The robot gets a better view of the plants because it can take pictures from a variety of locations and angles. As a result, it can detect illnesses more precisely and cover a larger area with less equipment. This system can also be applied to a variety of plants and illnesses. Simply add more images to teach it what to look for. It works well for large farms as well as small backyard gardens. To get a good sense of how the plants are doing, you can even add additional devices, such as sensors that monitor the soil and weather.

Basically, a clever method of early detection of plant diseases is to use cameras and computer intelligence on a farm robot. It helps farmers make better decisions about their farms, works more quickly, and eliminates the need for them to go around inspecting every plant. This system helps produce more food in an environmentally friendly manner by monitoring the plants in real-time and alerting the farmer to any changes.

During testing, the system was able to identify sick plants early and promptly notify farmers. This is significant because it helps them maintain the health of their crops, lose fewer plants, and use less insecticide. This system is a significant step toward more intelligent farms that employ technology and computers to improve food production.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26jul051

Table 1 Plant Disease Detection Algorithm

Stage	Input	Method Used	Output
Image Acquisition	RGB Image	Resize, Gaussian Filter	RGB image
PreProcessing	Irgb	K-means Clustering	Resized images
Normalization	Leaf Image	CNN	Feature vector
Segmentation	HSV Image	Softmax classifier	Feature class
Classification	Feature vector	Argmax+IOT alert	Disease class
Decision& Alert	Disease class	Farmer Notification	Farmer Notification

V. IOT ENABLED SMART IRRIGATION CONTROL STRATEGY

Water must be used carefully on modern farms. Using too much or too little water during irrigation can damage crops, contaminate the soil, and waste resources. Based on the actual soil moisture content, this system uses the internet to regulate watering [9]. Without a human being present all the time, sensors, computer intelligence, and wireless technology ensure that the plants receive precisely the right amount of water. While connected to the internet, the water control operates independently [10]. From a distance, farmers can monitor events, maintain documentation, and keep an eye on things. In addition to saving water, this technology uses data to help farmers make better decisions [14].

➢ *Checking Soil and Getting Data*

The system determines how much water to use based on how wet the soil is. The water level is monitored by a ground-based sensor. A small computer (ESP32) receives a signal from it and converts it into data [12]. The sensor takes readings frequently in order to obtain accurate data. To eliminate any strange blips, the readings are averaged out. In this manner, the system can detect changes in the soil and respond to things like rain or plants absorbing water.

➢ *Deciding when to Water and Pesticide Spray*

Watering and pesticide spraying are managed by the ESP32 chip according to predetermined limits. It measures the moisture content of the soil before watering. It makes use of the AI's disease level diagnosis for pesticides. These restrictions are determined by the type of soil, the type of crop, and the severity of the disease. 1. How to Water The soil's water content is continuously monitored by the system. Watering begins if the moisture content is below the threshold.

- *Irrigation Control Logic*

To ascertain whether irrigation is necessary, the real-time soil moisture value is continuously compared with a predetermined moisture threshold. The mathematical expression for the irrigation control logic is:

$$I(t) = \{\begin{matrix} 1, & \text{if } M(t) < M_{th} \\ 0, & \text{if } (t) \geq M_{th} \end{matrix}$$

Where:

If M(t) < M_{th}, then I(t) = 1 (water on)

If M(t) ≥ M_{th}, then I(t) = 0 (water off)

I(t) = watering signal

M(t) = soil moisture at a certain time

M_{th} = the moisture limit

When the soil is too dry, to allow water to enter, ESP32 opens a valve. The valve stops overwatering and conserves water when it is sufficiently wet.

- *Pesticide Spray Control Logic*

The plant disease detection output from the image processing and machine learning module is used to regulate pesticide spraying. The ESP32 initiates the pesticide spraying mechanism when a disease is identified and its severity surpasses a predetermined threshold.

The reasoning behind pesticide control can be stated as follows:

$$(t) = \{\begin{matrix} 1, & \text{if } D(t) \geq D_{th} \\ 0, & \text{if } D(t) < D_{th} \end{matrix}$$

Where:

If D(t) ≥ D_{th} , then P(t) = 1 (spray on) If D(t) < D_{th} , then P(t) = 0 (spray off)

P(t) = spray signal

D(t) = disease level at a certain time

D_{th} = the disease limit If the disease is above the limit,

The ESP32 turns on a pump to spray pesticides only where they are needed. The pump stops working when the spraying is over or the disease is under control. This makes sure that pesticides are used carefully, which helps the environment and cuts down on waste.

➢ *Turning on the Water*

The water flow is controlled by a valve. It is safe because the ESP32 controls the valve with a switch. This system makes sure that the watering is done right without anyone having to do it by hand. This way of controlling the water gives the plants enough water without drowning them, which can hurt the roots and make them sick. The system saves water and makes watering more effective.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26jul051

➢ *Internet Hookup*

Wi-Fi lets the ESP32 computer connect to the internet. It sends information about the soil, watering, and alerts to the web. You can see this information on phones, tablets, and computers. Farmers can see their watering from anywhere because they are online. They get a message right away if something goes wrong, like the soil getting too dry or the system breaking down.

➢ *Running on its Own*

This watering system is designed to work on its own with little help. It can work on its own without someone watching it all the time because it has sensors, makes smart decisions, and waters itself. This is very useful for farms that are big or far away. The system works better when you use the internet. There is a backup of the data. You can quickly find out what is wrong and make the system bigger if you need to. This smart watering plan helps farms save money, water, and grow healthy crops.

VI. RESULT AND DISCUSSION

We built and tested a smart farm using AI and the Internet of Things. It has an ESP32 controller, sensors, and relays that all work together in real time. The tests were good. The system knew to turn off the water when the soil was wet enough (4095). The water level sensor also made sure there was enough water on hand if it was needed and opened the valve.

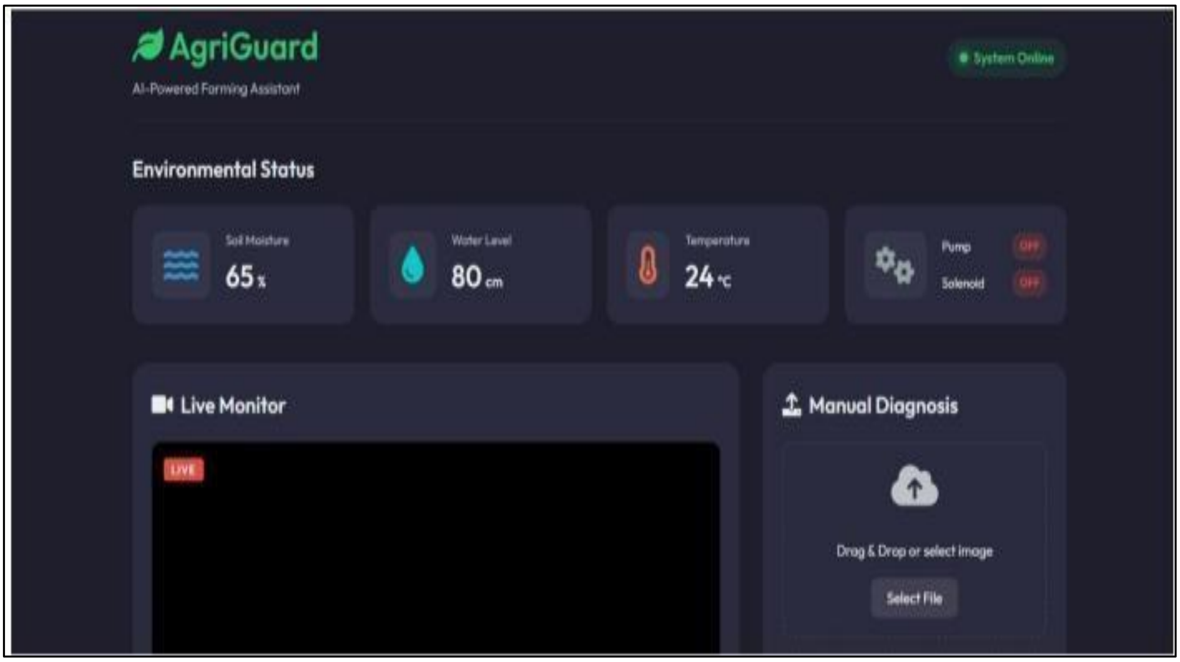

Fig 4 Web Page Dashboard

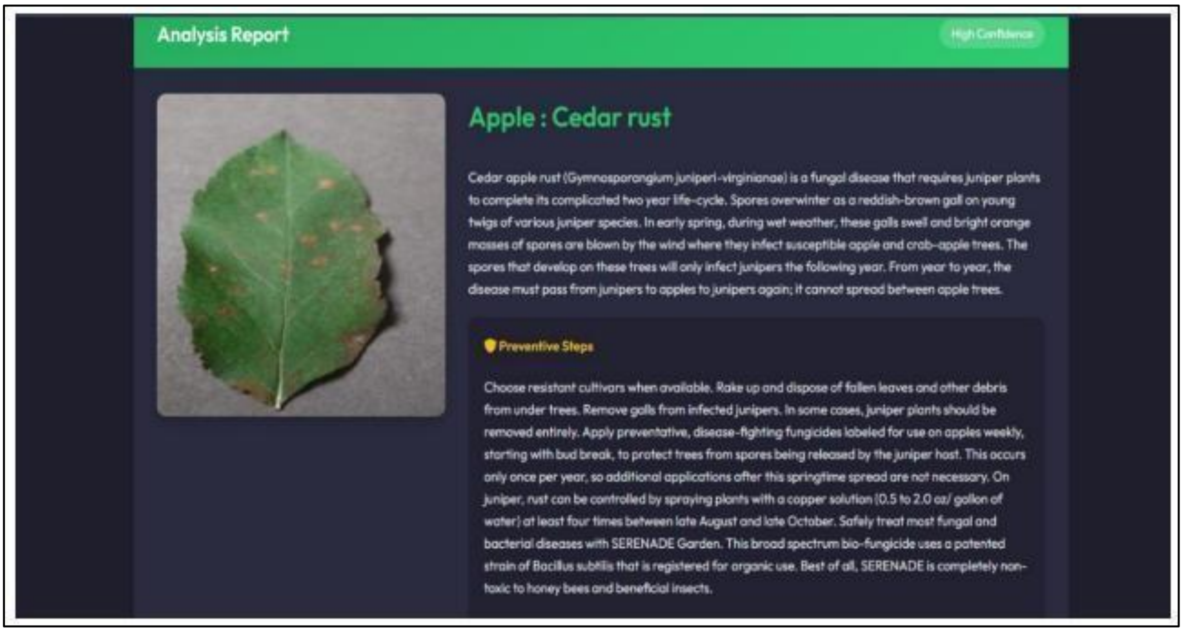

Fig 5 Leaf Disease Detection

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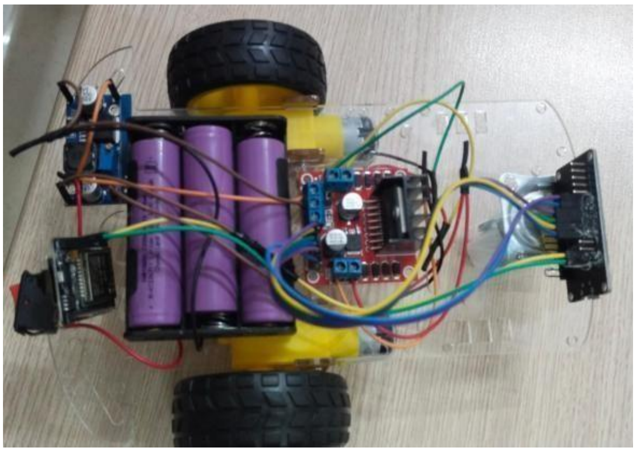

Fig 6 Car Bot

The AI part, which used a CNN model, found sick leaves by looking at their color and texture. This helps farmers find problems early and use fewer pesticides.

This AI and IoT system takes care of watering and watching over crops, which makes things easier for farmers and saves water. It's a great fit for farms that want to be exact.

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