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An Automated Robotic System For Diagnosing And Treating Plant Diseases Using Deep Learning

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Sincerely,

Daouia Charaa, Maria Ouled Haddar

Abstract

Plant diseases cause significant economic losses and pose a threat to sustainable agriculture. Farmers face problems related to crop infections and also during the spraying of pesticides, which can be toxic to them. To address these issues, we have developed an idea called "AGROBOT." The main goal of our idea is to detect the infection rate in plants and provide the appropriate pesticides for the disease. To achieve this, we devised an action plan to scale up our idea by creating a mobile vehicle that can move across a field, identify infected plants, take pictures of them using a camera, and send these images to a control processor (Raspberry Pi 5). The processor analyzes the problem based on the stored data and applies the appropriate pesticides to the farm.

Key words: Plant diseases;Economic losses; Sustainable agriculture; AGROBOT; Raspberry Pi5

Résumé

Les maladies des plantes causent des pertes économiques importantes et constituent une menace pour l'agriculture durable. Les agriculteurs sont confrontés à des problèmes liés aux infections des cultures et à l'application de pesticides qui peuvent être toxiques pour eux. Pour résoudre ces problèmes, nous avons conçu une idée appelée "AGROBOT". L'objectif principal de notre projet est de détecter le taux d'infection des plantes et de fournir les pesticides appropriés pour chaque maladie. Pour ce faire, nous avons élaboré un plan d'action visant à développer un véhicule autonome capable de se déplacer dans un champ agricole, de détecter les plantes infectées, de prendre des photos de celles-ci avec une caméra, et d'envoyer ces images à un processeur de contrôle (Raspberry Pi 5). Ce dernier analyse le problème en se basant sur les données stockées, puis applique les pesticides appropriés à la ferme.

Mots clés : Maladies des plantes ;Pertes économiques ;Agriculture durable ;AGROBOT; Raspberry Pi 5;

ملخص

تتسبب أمراض النباتات في خسائر اقتصادية كبيرة وتشكل تهديدًا للزراعة المستدامة كما ويواجه المزارعون مشاكل فيما يتعلق بإصابة محاصيلهم وأيضًا أثناء رش المبيدات الحشرية التي يمكن أن تكون سامة بالنسبة لهم، ومن أجل معالجة هذه المشاكل توصلنا إلى فكرة تسمى "AGROBOT". الهدف الرئيسي من فكرتنا هو اكتشاف معدل الإصابة في النبات وتوفير المبيدات المناسبة للمرض. ولتحقيق ذلك، توصلنا إلى خطة عمل لتوسيع نطاق فكرتنا من خلال إنشاء مركبة جوالة يمكنها التحرك عبر حقل زراعي وتحديد النبات المصاب والتقاط صورته بواسطة كاميرا وإرسالها إلى المعالج المتحكم(Raspberry pi5) حيث يقوم بتحليل المشكلة بناء على المعطيات المخزنة فيه وتطبيق المبيدات المعنية للمزرعة.

الكلمات المفتاحية: أمراض النبات؛ خسائر اقتصادية؛ الزراعة المستدامة؛ AGROBOT؛ Raspberry Pi 5

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List of Abbreviations

AI	Artificial Intelligence
CNN	convolutional Neural Network
Alex Net	Alex Network
VGG 19	Visual Geometry Group 19-layer Network
Inception-v1	Inception Version 1 Network
ResNet50	Residual Network 50-layer
LIDAR	Light Detection and Ranging
GPS	Global Positioning System
SLAM	Simultaneous Localization and Mapping

INTRODUCTION

Technology has revolutionized many areas, including agriculture. Since the 1970s and 1980s, robots have been used for tasks such as harvesting and spraying. As technology advances, these robots become more sophisticated, incorporating sensors and artificial intelligence, allowing them to perform a wide range of tasks more effectively. Today, robots can monitor crop health, diagnose diseases, manage irrigation and fertilization and control weeds, enhancing productivity and reducing environmental impacts. The continued use of robots is expected to improve agriculture, making it more sustainable and efficient to meet the growing food demand expected to double by 2050.[1]

Modern agriculture faces major challenges, especially in the field of sustainable food production to meet increasing population growth. Plant diseases pose a major threat, leading to significant crop losses and affecting global food security. Traditional methods of disease detection and classification are labor intensive, expensive, and dependent on human expertise, making them error-prone and ineffective in large agricultural areas. They also delay disease detection, complicating control efforts and increasing labor costs. Deep learning and robotics offer innovative solutions. Robots equipped with deep learning systems can accurately and quickly diagnose plant diseases, enabling timely preventive and remedial measures. These robots use image analysis and big data to identify disease patterns, improve diagnostic efficiency and reduce human intervention.

To address these challenges, several solutions have been proposed: using artificial intelligence to detect and predict plant diseases, deploying automated robots for monitoring and treatment, and developing an Android application for farmers to monitor plant health. The project also includes an electronic platform for disease detection and prediction, with the aim of determining the exact location of the disease’s spread and creating a map of the affected areas. This facilitates rapid intervention and saves time, effort and money. Project goals include comparing algorithms, designing and developing a robot, creating operational codes, and diagnosing diseases using Kaggle databases. The project aims to create an easy-to-use interface for users, and take advantage of the various sensors in the mobile robot to predict diseases. Every component and prototype will be tested to ensure correct navigation and disease detection. The importance of the project lies in enhancing agricultural efficiency, sustainability and productivity through advanced robotics and deep learning, and developing a system for managing plant diseases accurately and independently. The scope includes developing and testing robots and algorithms in different agricultural environments and providing an intuitive user interface to farmers.

SWOT analysis reveals strengths such as increased crop management efficiency, sustainable agriculture and reduced use of chemicals, improved production quality, reduced crop losses, enhanced disease prediction, and increased productivity. Weaknesses include high development and operating costs, limited integration into dynamic environments, reliance on complex technologies, potential for diagnostic errors, and limited ability to address diverse environmental challenges. Opportunities include growing demand for advanced agricultural technology, expanding application scopes, developing precision analysis techniques, creating jobs in agricultural technology, and leveraging big data for more intelligent models. Threats include security risks to automated systems, compliance issues with environmental regulations, challenges in transitioning to smart agriculture, concerns about lack of jobs, and technological impact on the ecological balance.

Chapter 1 : LITERATURE REVIEW

Chapter 1

LITERATURE REVIEW

1.1 Introduction

A literature review is a vital step that aims to explore similar ideas and examine the theoretical and applied approaches associated with them. Within our project focusing on plant disease diagnosis using deep learning techniques, we seek to analyze five distinct AI technologies: Alex Net, VGG19, Inception-v1, and ResNet50 , Inception-v3, VGG16. In addition, this chapter documents the different features of each technology to highlight the main differences and contradictions between them. Our project is the culmination of testing and comparing different algorithms with the aim of improving the accuracy and efficiency of plant disease diagnosis.[2]

1.2 Researched Articles

1.2.1 Alex Net

Alex Net is the name of a convolutional neural network (CNN) architecture designed by Alex Krizhevsky in collaboration with Ilya Sutskever and Geoffrey Hinton, which aims to compete in the ImageNet LSVRC-2010 Challenge. Alex Net was used for image classification at the 2012 ILSVRC competition, where it was able to classify images into one of thousands of different categories (e.g. cats, dogs) with high accuracy.

The input to Alex Net is an RGB image of size 256×256, and during image processing, random crops of size 227×227 were extracted for use in the network. Alex Net used new techniques at the time, such as ReLU to introduce nonlinearity and speed up training by a factor of six, Dropout to handle overfitting, and nested pooling to reduce the network size.

Alex Net consists of 5 convolutional layers and 3 fully connected layers, with ReLU applied after each layer as illustrated in Figure 1-1 .

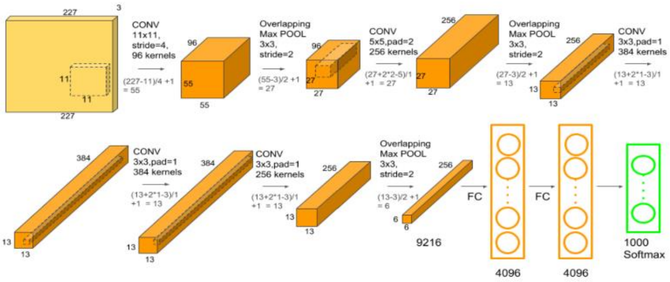


Figure 1-1 Alex Net Architecture

In the 2012 ImageNet Challenge, Alex Net achieved a top-5 error rate of 15.3%, 10.8 percentage points lower than the runner-up. Alex Net has proven that using supervised learning on large deep CNNs can achieve great results on large datasets. Alex Net has been a milestone in making deep learning more applicable in areas such as natural language processing and medical image analysis.[3]

1.2.2 VGG 19

Simonyan and Zisserman of the University of Oxford created a 19-layer (16 conv., 3 fully-connected) CNN that used 3×3 filters with stride and pad of 1, along with 2×2 max-pooling layers with stride 2 , called VGG-19 model.28,29 Compared to Alex Net, the VGG-19 (see Figure 1-2) is a deeper CNN with more layers. To reduce the number of parameters in such deep networks, it uses small 3×3 filters in all convolutional layers and is best utilized with its 7.3% error rate. The VGG-19 model was not the winner of ILSVRC30 2014, however, the VGG Net is one of the most influential papers because it reinforced the idea that CNNs have to have a deep network of layers in order for this hierarchical representation of visual data to work

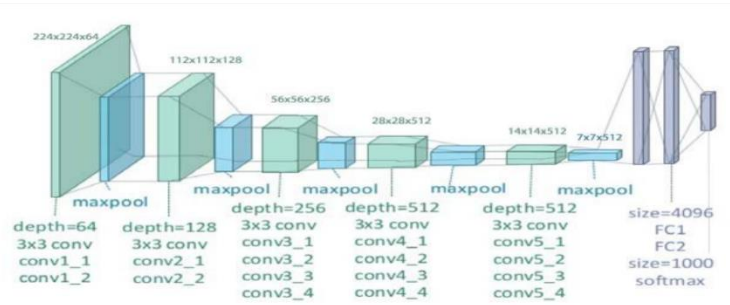


Figure 1-2 Illustration of the network architecture of VGG-19 model

The VGG-19 model, a total of 138M parameters, was placed 2nd in classification and 1st in localization in ILSVRC 2014. This model is trained on a subset of the ImageNet27 database, which is used in the ImageNet Large-Scale Visual Recognition Challenge (ILSVRC).30 The

VGG-19 is trained on more than a million images and can classify images into 1000 object categories. As a result, the model has learned rich feature representations for a wide range of images.[4]

1.2.3 Inception-v1

Inception is a type of architecture for convolutional neural networks (CNNs) used in computer vision. The main idea behind this architecture is to approximate the optimal local sparse structure in CNNs using readily available dense components. This is based on the assumption of translation invariance, meaning the network will be built from convolutional building blocks that are spatially repeated.

The basic units in the Inception architecture involve using a variety of convolutional filters of different sizes (such as 1×1, 3×3, and 5×5) at each stage, and their outputs are concatenated into a single output vector forming the input of the next stage. Additionally, a parallel pooling path (such as 3×3 max pooling) is added at each stage to achieve an additional beneficial effect. As the layers progress, the density of locally grouped units is reduced while the larger convolutions increase, allowing for capturing higher-level abstract features according to Figure 1-3 (a)

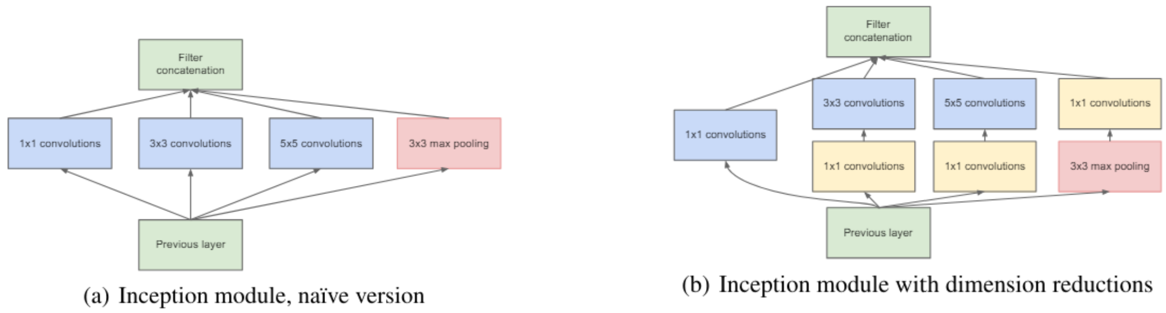


Figure 1-3 Inception module

To solve the problem of increased computational complexity, dimension reduction is intelligently applied using 1×1 convolutions before the more expensive 3×3 and 5×5 convolutions. These reductions allow for controlling computational resources, enabling an increase in the number of units at each stage without an uncontrolled blow-up in computational complexity. This design also allows for processing visual information at different scales and aggregating it so that the next stage can extract features from these multiple scales simultaneously.

Thus, this design allows for more efficient use of computational resources, increasing the width of each stage and the number of stages. It is also possible to create computationally cheaper versions of the network, resulting in networks that are faster than similarly performing networks without the Inception architecture according to Figure 1-3 (b). [5]

1.2.4 ResNet50

is a deep convolutional neural network (CNN) architecture developed by Microsoft Research in 2015. It is a variant of the Residual Network (ResNet) and has 50 layers. ResNet50 is notable for its use of residual connections, which allow the network to learn deeper architectures without suffering from vanishing gradients. The architecture is divided into four main parts:

1. **Convolutional Layers:** Extract features from the input image using several convolutional layers followed by batch normalization and ReLU activation. These are followed by max pooling layers.
2. **Identity Block:** Passes input through convolutional layers and adds the input back to the output, allowing the network to learn residual functions.
3. **Convolutional Block:** Similar to the identity block but includes a 1x1 convolutional layer to reduce the number of filters before the 3x3 convolutional layer.
4. **Fully Connected Layers:** Used for final classification, with the output fed into a SoftMax activation function to produce class probabilities as depicted in Figure 1-4.

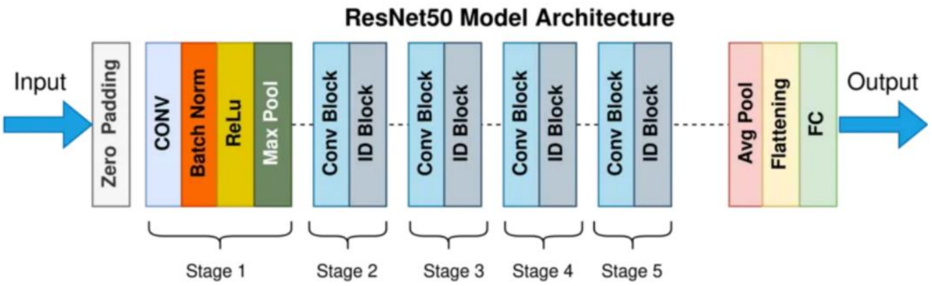


Figure 1-4 ResNet50 Architecture

ResNet50 has achieved state-of-the-art results on benchmarks like the ImageNet dataset, with an error rate of 22.85%, which is close to human performance.[6]

1.2.5 Inception-v3

Inception-V3 is an advanced version of the Inception neural network architecture designed to improve performance and computational efficiency on image classification tasks, such as the ILSVRC 2012 classification benchmark. The key innovation in Inception-V3 is the factorization of larger convolutions into smaller ones; for instance, a traditional 7×7 convolution is broken down into three 3×3 convolutions. This reduces the computational cost while maintaining the model's ability to capture complex features. In Inception-V3, the network begins

with several convolutional and pooling layers to preprocess the input image. Then, it employs multiple Inception modules, each containing convolutions of various sizes (1×1, 3×3, 5×5) and pooling operations to capture features at different scales.

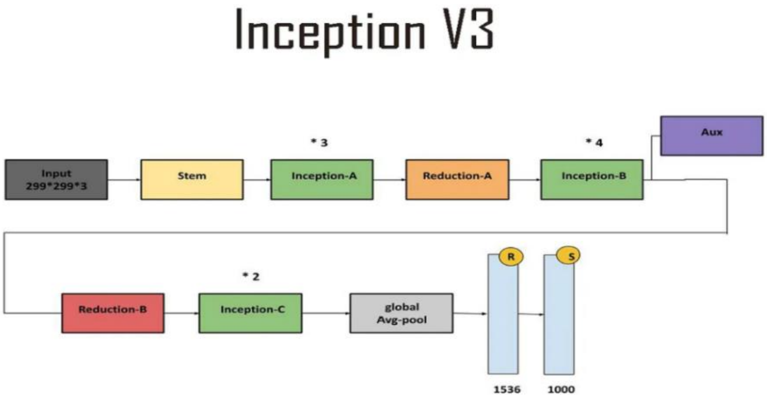


Figure 1-5 Inception-v3 module

The architecture includes grid reduction techniques to progressively reduce the spatial dimensions of the feature maps, ensuring computational efficiency. Specifically, the network features three traditional Inception modules with 288 filters each at the 35×35 grid size, followed by a reduction to a 17×17 grid with 768 filters using the described grid reduction techniques. This is followed by five instances of the factorized Inception modules, which further reduce the grid to an 8×8×1280 size. At the coarsest 8×8 level, there are two Inception modules with a combined output filter bank size of 2048. The final layers of the network include global average pooling, a fully connected layer, and a softmax classifier to produce the final class probabilities.

Despite being 42 layers deep, Inception-V3 manages to keep computational costs approximately 2.5 times higher than Google Net, but it remains significantly more efficient than VGGNet based on Figure 1-5. [7]

1.2.6 VGG 16

The VGG-16 model is a convolutional neural network (CNN) architecture proposed by the Visual Geometry Group (VGG) at the University of Oxford. It consists of 13 convolutional layers, 5 max pooling layers, and 3 fully connected layers, making it have 16 layers with adjustable parameters (hence the name VGG16). The number of filters starts with 64 in the first block and doubles in each subsequent block until it reaches 512. The model ends with two fully connected hidden layers, each containing 4096 neurons, followed by an output layer containing 1000 neurons, corresponding to classes in the ImageNet dataset. VGG-16 is known for its simplicity and effectiveness, as well as its ability to achieve strong performance in various computer vision tasks, including image classification and object recognition. This design enables the model to learn complex hierarchical representations of visual features, leading to robust and accurate predictions as shown in Figure 1-6.

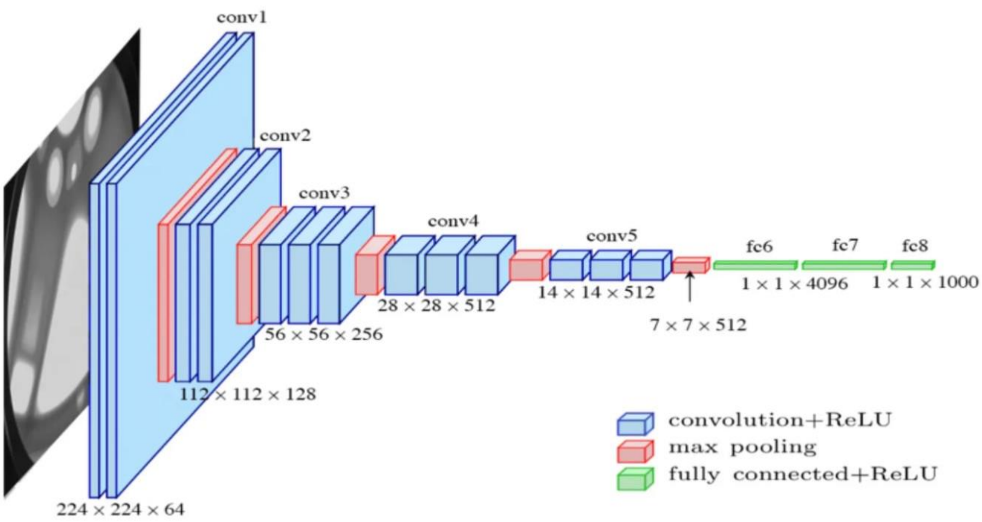


Figure 1-6 The architecture of VGG16

Despite its simplicity compared to newer architectures, VGG-16 remains a popular choice for many deep learning applications due to its versatility and excellent performance.

The ImageNet Large-Scale Visual Recognition Challenge (ILSVRC) is an annual computer vision competition in which teams undertake tasks including object localization and image classification. VGG16, proposed by Karen Simonyan and Andrew Zisserman in 2014, achieved top rankings on both tasks, detecting objects from 200 categories and classifying images into 1,000 categories. The model achieved a top-5 testing accuracy of 92.7% on the ImageNet dataset containing 14 One million images belonging to 1000 categories.[8]

1.3 Comparative Analysis

In this table, we present the most important CNN algorithms in the field of plant disease diagnosis and the comparison process between them to determine the most efficient algorithm.

Table 1.1: Comparative Analysis

Algorithm	Accuracy	Recall	Training Speed	Inference Speed	Memory Usage
Alex Net	Good	Good	Medium	Fast	Medium
VGG19	High	High	Slow	Medium	Very High
InceptionV1	Very Good	Very Good	Medium	Medium	High
ResNet50	Excellent	Excellent	Slow	Medium	High
InceptionV3	Excellent	Excellent	Slow	Medium	High
VGG16	High	High	Slow	Medium	Very High

1.4 Conclusion

In this chapter, we compare the main algorithms for plant disease diagnosis based on scientific literature. We highlighted the strengths and weaknesses of each algorithm, given that InceptionV3 is difficult to train, the high complexity of its architecture, and takes longer to train. We chose ResNet50 for its high precision and recall, despite its high memory usage. Therefore, we chose it for our project due to its superior performance in diagnosing plant diseases. In the upcoming chapters, we will delve into the design, methodology, implementation, and navigation of our robot

Chapter 2:

METHODOLOGY, DESIGN AND ANALYSIS

Chapter 2

METHODOLOGY, DESIGN AND ANALYSIS

2.1 Introduction

Initially this chapter deals with the definition of the methodology that will be used to design and implement the project in the 2.2 "methodology" section. The department clarifies how steps and methods will be adopted to achieve the goals specified efficiently and effectively. In section 2.3 "design components and alternatives", the focus is on the analysis of the design components and possible alternatives carefully to choose the optimal option. Then, in section 2.4 "design and description of an automatic treatment spray system", a detailed system design is provided with technical specifications and various functions. In the 2.5 "conclusion" section, it focuses on reviewing previous results and conclusions, discussing expected performance, potential challenges and ethics related to the project.

2.2 Methodology

The methodology employed plays a crucial role in identifying, streamlining, and executing the project's tasks within the allotted time frame. It's important to acknowledge that the chosen methodology has the potential to significantly influence the final outcome of the project.

Figure 2-1 The Agile methodology

Therefore, pinpointing the most suitable approach enhances the likelihood of project advancement in the most effective manner. Given the project's extensive scale and breadth, gradual adjustments are necessary, thus making the incremental Agile model the predominant methodology, as depicted in Figure 2.1.

Table 3.1 presents both the strengths and weaknesses of adopting the Agile model approach.

Table 2-1 The Advantages and disadvantages of the Agile methodology

Advantages	Disadvantages
• Responding to changes. • Continuous cooperation. • Providing repeated deliveries. • Focus on quality. • Stimulation of the team.	• The complexity of the administration. • Determine the variable domain. • The difference between the difference. • Continuous learning. • Cost control.

2.3 Design Components and Alternatives

2.3.1 Microcontroller/Microcomputer Device

2.3.1.1 Arduino Mega

The Arduino Mega 2560 is a hardware solution compatible with Arduino that incorporates Bluetooth 4.0 (BLE) functionality. Targeted towards makers, educators, and developers, the Arduino Mega 2560 has facilitated the development of numerous notable prototypes from initial concept to realization.

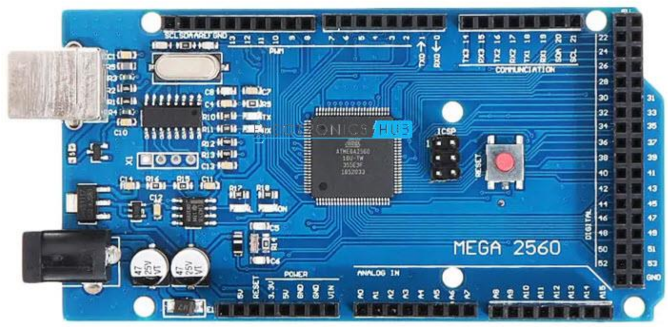


Figure 2-2 Arduino Mega 2560 Microcontroller [10]

The Arduino Mega 2560 is a flagship microcontroller board powered by the ATmega2560 chipset, known for its robust performance and versatility. It features 54 digital I/O pins (15 PWM outputs), 16 analog inputs, and 4 UARTs for extensive connectivity. Designed for ease of use, it includes a 16 MHz crystal oscillator, USB connection for programming, power jack for flexible power options, an ICSP header, and a reset button (see Figure 2-2). Compatible with various shields, the Mega 2560 offers expandability and versatility, making it ideal for both beginners and experienced developers to bring their projects to life.

2.3.1.2 Raspberry Pi

Raspberry Pi serves as a potential substitute for Arduino-based microcontrollers due to its characteristics and capabilities resembling those of a small single-board computer (SBC). Widely recognized for its affordability and compact size, Raspberry Pi is small enough to be held in the palm of a hand, as illustrated in Figure 2.3.

Figure 2-3 Raspberry Pi Board [11]

Furthermore, Raspberry Pi offers users the flexibility to program in Scratch or Python languages and operates on the Linux operating system. Additionally, Raspberry Pi single-board computers (SBCs) possess higher computing and processing capabilities compared to Arduino microcontrollers, as they are microprocessors rather than microcontrollers. However, the increased processing power of Raspberry Pi may be unnecessary for tasks such as operating vibration motors.

2.3.1.3 Arduino Uno

When delving into electronics and coding for the first time, the Arduino UNO stands out as the ideal board to begin your journey. Renowned for its reliability, it's the most recommended board for beginners due to its extensive documentation and widespread usage within the Arduino family, which is small enough to hold in the palm of the hand, as shown in Figure 2.4.

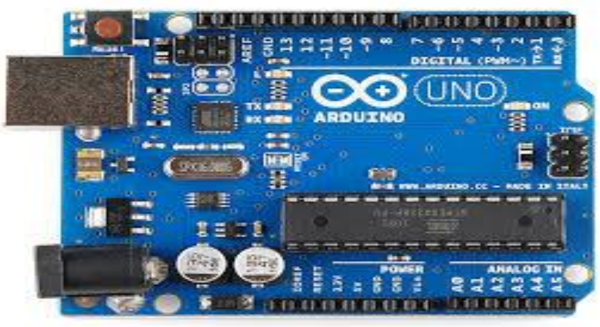


Figure 2-4 Arduino Uno[12]

The Arduino UNO, powered by the ATmega328P microcontroller, features 14 digital I/O pins (6 PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator, USB connectivity, a power jack, an ICSP header, and a reset button. It provides all necessary support for the microcontroller, making it easy to begin by connecting to a computer via USB cable or powering it with an AC-to-DC adapter or battery. With the UNO, experimentation is encouraged without fear of irreversible mistakes; in the worst-case scenario, the chip can be replaced inexpensively, allowing you to start anew.

2.3.1.4 Team's Decision

In the end, we decided to choose Raspberry Pi for its large storage capacity, making it suitable for handling images and other data-intensive tasks. Additionally, we opted for Arduino UNO for its ease of use and simplicity in controlling robot movements, making it the optimal choice for such projects. This combination enhances the strengths of both systems, providing robust performance and ease of development for various project requirements.

2.3.2 Device Software

2.3.2.1 Python

Python boasts broad compatibility with diverse platforms and a rich repository of code examples. Its intuitive interface makes it accessible even to beginners and non-technical users (see Figure 2-5). However, Python may face challenges in handling larger-scale projects. Notably, Python is freely available for use.

Figure 2-5 Python Software [13]

Python is versatile, powering tasks from data analysis to web development, automation, software testing, and even everyday chores like financial organization.

2.3.2.2 Arduino IDE

The Arduino IDE supports a variety of Arduino boards and offers extensive code examples within its library as illustrated in Figure 2-6. It's particularly user-friendly for beginners and non-STEM students, although it does have some drawbacks like difficulties in managing larger projects. Nonetheless, it's worth noting that the Arduino IDE is available at no cost.

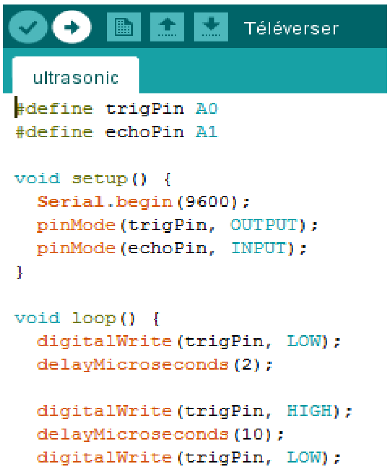


Figure 2-6 Arduino IDE Software

2.3.2.3 Programino IDE for Arduino

Programino IDE for Arduino serves as an alternative to the Arduino IDE, offering Arduino users the ability to write code in C/C++ languages instead of the standard Arduino programming language. Programino IDE empowers users to develop their own code for Arduino boards and provides additional tools, granting users greater flexibility in their coding endeavors

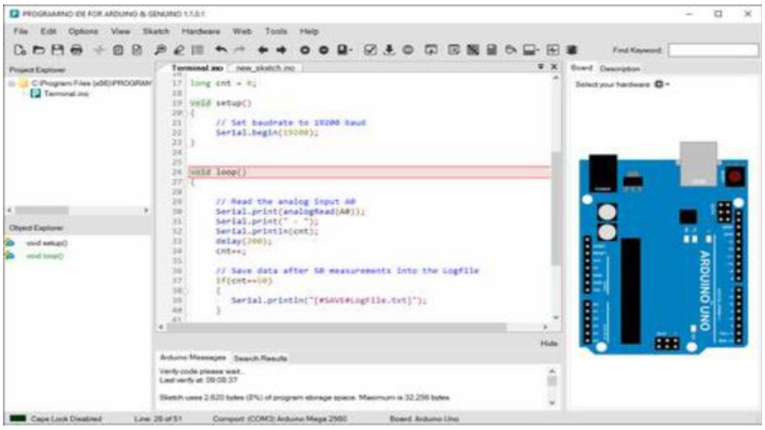


Figure 2-7 Programino IDE Software [14]

Nonetheless, Programino IDE exhibits certain limitations, especially when compared to Arduino IDE. Due to Arduino IDE's status as the primary software for Arduino boards, Programino IDE lacks the comprehensive technical and hardware support necessary to rival it. For instance, Programino IDE is only capable of sending codes to older and officially supported Arduino boards straight out of the box. Consequently, Programino IDE proves unsuitable for newer versions of Arduino boards as depicted in Figure 2-7 .

2.3.2.4 Team's Decision

Finally, we opted to use the standard Arduino IDE over Programino IDE for several reasons. Not only does Programino lack hardware support, especially in unforeseen emergency situations, but it also lacks external ports to assist us in navigating through emergencies, limiting our ability to execute the AGROBOT project. Additionally, Arduino IDE is free, whereas Programino comes with a fixed price. Furthermore, we chose Python for its capability in data analysis, machine learning, software testing, and prototyping models.

2.3.3 Mobile Robot Platform

2.3.3.1 Quadruped Robot

The quadruped robot (see Figure 2-8) is an advanced device designed to move independently on the ground, making it ideal for working in rugged and diverse agricultural environments. The quadruped robot is used for diagnosing and treating plant diseases by equipping it with a set of sensors and cameras that allow it to inspect plants at ground level. This robot can move between crop rows, analyze soil and plant data accurately, and detect issues such as diseases, pests, or nutrient deficiencies.

Figure 2-8 Quadruped Robot Platform [15]

Additionally, it can be equipped with tools for applying treatments, such as precision sprayers, to directly treat affected plants.

2.3.3.2 Drone

The drone, also known as an unmanned aerial vehicle (UAV) (see Figure 2-9), is a flying device controlled remotely or operating autonomously using software. Drones are used for diagnosing and treating plant diseases due to their ability to fly over large agricultural areas and capture high-resolution aerial images with multispectral cameras and sensors. These images enable farmers and researchers to analyze plant health and detect issues such as diseases, water stress, or nutrient deficiencies quickly and accurately. Additionally, drones can be equipped with spraying systems to effectively apply treatments to affected plants.

Figure 2-9 Drone [16]

2.3.3.3 Team's Decision

Finally, we chose to use a four-legged robot to diagnose and treat plant diseases. The four-legged robot excels at close inspection, direct interaction with plants, and the ability to navigate rugged agricultural environments. In addition, in the event of a malfunction in the robot device AGROBOT, it will remain in place in order to maintain it, and this does not happen in the drone, as if it has a malfunction, it will fall and crash. This makes AGROBOT the superior choice for targeted treatments and achieving the highest levels of efficiency and productivity in farms.

2.3.4 Ultrasonic Sensor

2.3.4.1 URM06 Pulse

The URM06 PULSE, available at DF Robot, represents a cutting-edge ultrasonic component noted for its exceptional capabilities in detecting distances ranging from 20 centimeters to 10 meters, making it one of the most advanced products on the market for short-range to long-range detection.

Figure 2-10 URM06 ultrasonic sensor

On the other hand, the URM06 is considered less cost-effective compared to other ultrasonic sensor products on the market. Despite this, it is renowned for its high camera resolution and is highly valued for its accuracy and versatile applications based on Figure 2-10.

2.3.4.2 HC-SR04

The HC-SR04 Ultrasonic Distance Sensor is used for detecting the distance to an object using sonar, making it ideal for robotics projects that require object avoidance. By measuring how close objects are, it helps steer robots away from them.

Figure 2-11 HC-SR04 ultrasonic sensor [17]

This sensor uses non-contact ultrasound sonar to measure distances. It consists of two ultrasonic transmitters (speakers), a receiver, and a control circuit. The transmitters emit a high-frequency ultrasonic sound that bounces off nearby solid objects, and the receiver listens for the return echo. The control circuit processes this echo to calculate the time difference between when the signal was transmitted and received as shown in Figure 2-11.

2.3.4.3 Team's Decision

We ultimately chose the HC-SR04 ultrasonic sensor instead of the URM06 sensor because the HC-SR04 is much less expensive and offers a wide range of accuracy. Although the URM06 is the most advanced product on the market, providing short-range to long-range detection from 20cm to 10m, its high price range is beyond our budget constraints.

2.3.5 Machine Vision Sensor

2.3.5.1 Web Camera

A webcam is a digital camera that captures video and audio data and transmits it in real-time over the Internet. It is frequently used for video conferencing, live streaming, online meetings, and video recording.

Figure 2-12 Web Camera [18]

Webcams are typically connected to computers or laptops via USB ports and are often integrated into devices such as laptops or external monitors. Additionally, they are compatible with Raspberry Pi, making them versatile tools for various applications according to Figure 2.12.

2.3.5.2 Raspberry Pi 5 Camera Module (Omni Vision OV5647)

The Raspberry Pi 5 Camera Module (Omni Vision OV5647) is an innovative camera designed for use with Raspberry Pi boards

Figure 2-13 Omni Vision OV5647 [19]

. It features a 5-megapixel sensor, capable of capturing images at 2592 × 1944 pixels and recording 1080p video at 30 frames per second. Its small and lightweight design makes it ideal for applications such as surveillance, robotics, and photography. It easily connects via the CSI interface on Raspberry Pi boards, ensuring seamless integration and easy installation as illustrated in Figure 2-13.

2.3.5.3 Team's Decision

We chose the Raspberry Pi Camera Module 5 due to its compatibility with most Raspberry Pi models, making it ideal for educational and hobbyist projects. It performs well in various lighting conditions and supports numerous software tools. This decision contrasts with choosing a web camera, which generally has lower resolution and produces less clear images, despite being more cost-effective and offering extensive hardware support for beginners.

2.3.6 Indoor Positioning System

2.3.6.1 Wi-Fi Indoor Positioning System by Assystem

The Wi-Fi indoor positioning system by AV System, known as Linkify Location Engine (LLE), is widely recognized as a popular Wi-Fi location-based service. It detects Wi-Fi and BLE devices to determine the precise position of Wi-Fi users, as illustrated in Figure 2.14.

Figure 2-14 Wi-Fi indoor positioning system by AV system

The service employs various machine learning algorithms to collect essential data on user insights and behavior patterns, enhancing the satisfaction of users and guests.

2.3.6.2 GPS

The Global Positioning System (GPS) uses signals from satellites and ground stations to accurately determine its position on Earth, and the NEO-6M GPS receiver module communicates with a microcontroller or PC terminal via USART to receive information such as latitude, longitude, altitude, and UTC time from satellites in the form of NMEA strings, which need to be parsed to extract usable information according to Figure 2-15.

Figure 2-15 GPS Module [20]

This GPS receiver plays a crucial role in various applications within agricultural robotics, facilitating tasks such as plant disease diagnosis, robotic navigation in fields, and overall fleet management for efficient agricultural operations.

2.3.6.3 Bluetooth

Bluetooth Arduino offers several advantages, including its ability to simultaneously connect multiple devices in the same environment and provide high accuracy in data transmission over short distances. This technology enables seamless communication between Arduino boards and various sensors, actuators, and mobile devices. It supports low-power consumption, making it suitable for applications requiring extended battery life.

Figure 2-16 HC-05 Bluetooth Module [21]

Additionally, Bluetooth Arduino interfaces well with common development platforms and libraries, enhancing its versatility and ease of integration into diverse projects and IoT applications based on Figure 2-16.

3.3.6.4 Team’s Decision

Finally, we chose Bluetooth and GPS for their specific advantages over traditional Wi-Fi indoor positioning systems. Bluetooth technology provides low power consumption and reliable short-range connectivity, making it ideal for long battery life applications. GPS provides global coverage and high accuracy outdoors using satellite signals. In contrast, indoor Wi-Fi positioning systems such as Assystem may be more widely used, but can have accuracy limitations in complex indoor environments and pose security concerns compared to Bluetooth and GPS.

2.3.7 Motor

2.3.7.1 DC-motors

A DC motor is an electrical motor that uses direct current (DC) to produce mechanical force, relying on magnetic forces generated by currents in the coils. Nearly all DC motors have an internal mechanism to periodically change the direction of the current. DC motors power robots that navigate fields, with their speed being widely adjustable by changing the supply voltage or current in the field windings, allowing for precise movement in various conditions as shown in Figure 2-17.

Figure 2-17 DC-motors 12VDC [22]

Small DC motors are ideal for this application due to their compact size and efficiency. They enable the robot to maneuver accurately within the field. Additionally, the use of DC motors supports the integration of various sensors and tools necessary for the robot's diagnostic functions.

2.3.7.2 Stepper Motor (Bipolar 200 Steps/Rev)

Stepper motors are ideal for robotics due to their discrete step movements, as depicted in Figure 2.18. They convert electrical pulses into precise angular steps, offering high torque and accuracy.

Figure 2-18 Stepper motor [23]

The Bipolar 200 Steps/Rev Stepper Motor is favored in mobile robotics for its precise angular positioning. It is also well-suited for various applications, including 3D printers, CNC machines, scanners, and hard drives.

2.3.7.3 Servo Motor

A servo motor is an electrical device used to precisely rotate objects, such as a robotic arm. It consists of a DC motor with an error-sensing negative feedback mechanism, allowing for precise control over the motor's angular velocity and position. In some cases, AC motors are used.

Figure 2-19 Sensors Modules Servo Motor [24]

This closed-loop system uses negative feedback to control the motion and final position of the shaft. Unlike conventional AC/DC motors, it is not used for continuous rotation, with a rotation angle ranging from 0° to 180° according to Figure 2-19.

2.3.7.4 DC Water Pump

This DC 3-6V Mini Micro Submersible Water Pump is an affordable, compact pump motor that operates on a 2.5 to 6V power supply. It can pump up to 120 liters per hour while consuming only 220mA of current as depicted in Figure 2-20.

Figure 2-20 5v DC Pump[25]

2.3.7.5 Team's Decision

We decided to use the DC motor because it is the most suitable motor for our Quadruped Robot, especially since it was included with the Quadruped Robot, eliminating any additional costs. Although other motor options, such as the servo motor, are also good, they do not appear to be as compatible with the Quadruped Robot. Additionally, we chose the servo motor to control the camera movement, allowing it to fully scan the plants.

2.3.8 Motor Shield (Motor Driver)

2.3.8.1 L293D Motor Driver Shield

The L293D Motor Driver Shield for Arduino is one of the most versatile options available, featuring 2 servo connectors and 4 motor connectors for DC or stepper motors, making it ideal for robotic projects. This shield can drive 4 DC motors or two 4-wire steppers and two 5V servos. It uses the L293D to drive DC motors and steppers, and Arduino pins 9 and 10 to drive servos according to Figure 2-21.

Figure 2-21 L293D Motor Driver Shield [26]

The shield includes two L293D motor drivers and one 74HC595 shift register, which expands 3 Arduino pins to 8 pins to control motor direction. The L293D's output is connected to the PWM outputs of the Arduino.

2.3.8.2 Driver Motor L298N

The L298N is a dual full-bridge high current motor driver board, widely used for controlling various types of motors. It can effectively drive a single stepper motor, two bidirectional DC motors, or control two relays. Each channel of the L298N is capable of handling a peak current of 3A and a continuous current of 2A. For applications requiring higher current capacity, the two channels can be paralleled to provide a single channel capable of handling up to 6A peak current and 4A continuous current as illustrated in Figure 2-22.

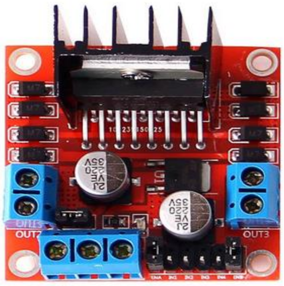


Figure 2-22 L298N Motor Driver [27]

This versatility makes the L298N ideal for powering motors in robotics, automation, and other high-current applications

2.3.8.3 Relay

A relay is an electronic switch that can be controlled by an Arduino microcontroller to turn a water pump on and off. When the relay is energized, it closes the electrical circuit, allowing current to flow and activate the pump. When de-energized, the relay opens the circuit, cutting off the current and turning the pump off based on Figure 2-23.

Figure 2-23 Relay Module for Efficient Device Control [25]

To control a water pump with an Arduino using a relay, we can connect the relay to the Arduino's digital output pins. The relay usually has three pins: VCC, GND, and IN. We connect VCC to the Arduino's 5V, GND to the GND, and IN to a digital pin. With these connections, we can use the Arduino's digital Write function to switch the relay on and off, thereby controlling the water pump.

2.3.8.4 Team's Decision

We opted for the L293D Motor Driver Shield for our mobile robot platform because it is specifically designed for DC motors, aligning perfectly with our project requirements. Unlike the L298N motor driver, which supports only two motors, the L293D Shield is designed for four motors, making it more cost-effective and efficient for our needs. It integrates seamlessly with the Quadruped Robot, providing reliable control and operation for our DC motors.

2.3.9 Battery

2.3.9.1 Li-ion Rechargeable Battery (3.7v 8800mAh)

A Li-ion (Lithium-ion) Battery rated at 3.7V and 8800mAh is a rechargeable battery commonly used in various portable electronic devices. This type of battery is versatile and finds applications in smartphones, tablets, digital cameras, portable media players, and various electronic gadgets that require a reliable power source (see Figure 2-24).

Figure 2-24 Li-ion Battery 3.7v 8800mAh [28]

Additionally, it is suitable for powering motors in robotic applications, providing a stable and long-lasting power supply for efficient operation of robotic systems.

2.3.9.2 Li-Ion cell 1200mAh

The 1200mAh lithium-ion cell is a rechargeable battery widely employed in electronic devices like flashlights, power banks, and electric vehicles. With a capacity of 1200mAh, this cell can store a total energy of 1200 milliampere-hours, enabling it to supply a continuous current of 1.2 amps for one hour, or 0.6 amps for two hours, and so forth (see Figure 2-25).

Figure 2-25 Li-Ion cell 1200mAh [29]

Lithium-ion cells are recognized for their high energy density, extended cycle life, and minimal self-discharge rates. They are also lightweight and compact, making them ideal for powering portable devices.

2.3.9.3 Team's Decision

We chose the Li-ion Battery 3.7v 8800mAhy due to its lower cost compared to the Li-Ion cell 1200mAh and its higher capacity of 88000mAh, whereas the Li-Ion cell has a capacity of 1200mAh.

2.4 Automated Plant Disease Detection and Treatment System

2.4.1 Disease Detection Using Sensors and Imaging Technology

2.4.1.1 Camera System for Plant Imaging

The Raspberry Pi Camera Module 5 is a high-resolution camera that provides clear and precise images of plants.

To capture comprehensive images of the plant from multiple angles, the camera is mounted on a servo motor (see Figure 2-26). This setup allows the camera to rotate around the plant, ensuring all sides are captured. The servo motor provides precise control of the camera position, enabling the following movements:

Horizontal rotation: from 0 to 180 degrees

Vertical tilt: from 0 to 90 degrees

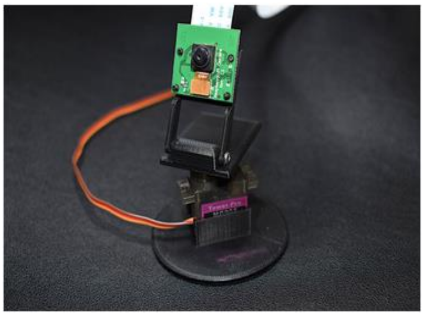


Figure 2-26 Raspberry Pi Camera on Servo for Panning [30]

The imaging process involves setting up the camera system, capturing images from multiple angles, and processing these images to create a detailed and comprehensive view of the plant.

The imaging process involves setting up the camera system, capturing images from multiple angles, and processing these images to create a detailed and comprehensive view of the plant.

- ✓ The camera is mounted on the servo motor and calibrated to ensure it starts at the correct angle.
- ✓ The servo motor rotates the camera around the plant, capturing images at a 10 degree angle

- ✓ The camera captures a series of images at each angle, which can be stitched together for a complete view of the plant.
- ✓ The captured images are processed and stitched together to create a 3D model or panoramic view of the plant.
- ✓ The camera is connected to the Raspberry Pi via the Camera Serial Interface (CSI), a dedicated interface for high-speed data transfer between the camera and the Raspberry Pi.
- ✓ Once an image is captured, it is transmitted to the Raspberry Pi, where it is stored for further processing.
- ✓ The Raspberry Pi processes the images using software algorithms that can stitch multiple images together to create a complete view of the plant.
- ✓ These stitched images can be used to create a 3D model or panoramic view of the plant, providing a comprehensive visualization.

2.4.1.2 Disease Detection from Image Data

The process involves capturing high-resolution images, transmitting them to the Raspberry Pi for preprocessing and feature extraction, and comparing these features against a database to detect and identify plant diseases.

- ✓ The images are preprocessed to enhance features relevant to disease detection, such as adjusting brightness and contrast or removing noise.
- ✓ Specific features that indicate plant health are extracted from the images. This includes color, texture, and patterns that may suggest the presence of disease.
- ✓ The extracted features are compared against a database of known disease markers. This database contains images and data of plants affected by various diseases, serving as a reference for comparison.
- ✓ The system uses algorithms to match patterns in the captured images with those in the database, identifying potential diseases based on similarities.
- ✓ Once a disease is detected, the system can alert the farmer to the presence of the disease and provide recommendations for treatment.
- ✓ The data can be further analyzed to determine the severity of the disease and the best course of action for treatment.

2.4.1.3 Flow of Data and Control

The flow of data and control in the system outlines how information is captured, processed, and utilized to maintain plant health. This process involves multiple stages, from the initial image capture by the Raspberry Pi Camera Module 5 to the final display of analyzed results on a custom-developed application. Each step is crucial for ensuring accurate disease detection and effective communication with the farmer. The following sections detail the sequential flow of data and the control mechanisms that facilitate real-time monitoring and response to plant health conditions.

- ✓ The camera captures an image and sends it to the Raspberry Pi via the CSI interface.
- ✓ The Raspberry Pi stores the image in its memory for processing.
- ✓ The stored images are processed to enhance and extract relevant features.
- ✓ The Raspberry Pi compares these features against a preloaded database of disease markers.
- ✓ If a disease is detected, the Raspberry Pi generates an alert. The alert includes details about the type of disease detected and recommended actions for treatment.

2.4.1.4 User Interface

The results are displayed on a custom-developed application that is connected to the robot. This application allows the farmer to access the results remotely through a network connection, providing real-time updates on the field conditions. The interface offers visual representations of detected issues and suggested remedies, ensuring that the farmer stays informed about what is happening in the greenhouse and can take timely actions to maintain plant health. The application integrates seamlessly with the robot, enabling continuous monitoring and easy access to crucial information.

2.4.1.5 Environmental Monitoring System

The environmental monitoring system uses humidity and temperature sensors to measure the conditions within the greenhouse. These measurements help farmers make informed decisions to maintain optimal growing conditions and prevent plant diseases.

2.4.1.5.1 Humidity and Temperature Sensors

The humidity sensor used in the environmental monitoring system is a critical component for maintaining optimal growing conditions within the greenhouse. This sensor continuously measures the moisture content in the air, providing essential data to help prevent plant diseases and promote healthy growth as illustrated in Figure 2-27.

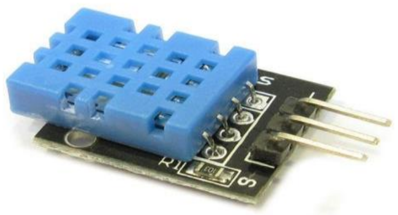


Figure 2-27 Temperature Humidity Sensor Module, 5.5v [31]

- ✓ The sensors continuously measure the humidity and temperature within the greenhouse.
- ✓ The sensor continuously sends real-time humidity data to the Raspberry Pi.
- ✓ The collected data is used to assess the environmental conditions, providing real-time information to the farmer through a custom-developed application.
- ✓ The data helps farmers decide when to ventilate the greenhouse, ensuring that humidity levels remain within the optimal range to prevent mold and fungal diseases.
- ✓ The real-time data allows farmers to make informed decisions about ventilation, irrigation, and other critical aspects of plant care. The application displays this data, enabling farmers to quickly respond to changing conditions in their greenhouse.

The combination of high-resolution imaging from the Raspberry Pi Camera Module 5 and environmental monitoring using humidity and temperature sensors provides a comprehensive system for maintaining plant health (see Figure 2-28). The imaging system ensures detailed monitoring of plant conditions, while the environmental sensors help maintain optimal growing conditions, preventing diseases and promoting healthy plant growth. The custom-developed application integrates both systems, allowing farmers to access real-time data and results, ensuring they stay informed about the conditions in their greenhouse and can take timely actions to protect their crops.

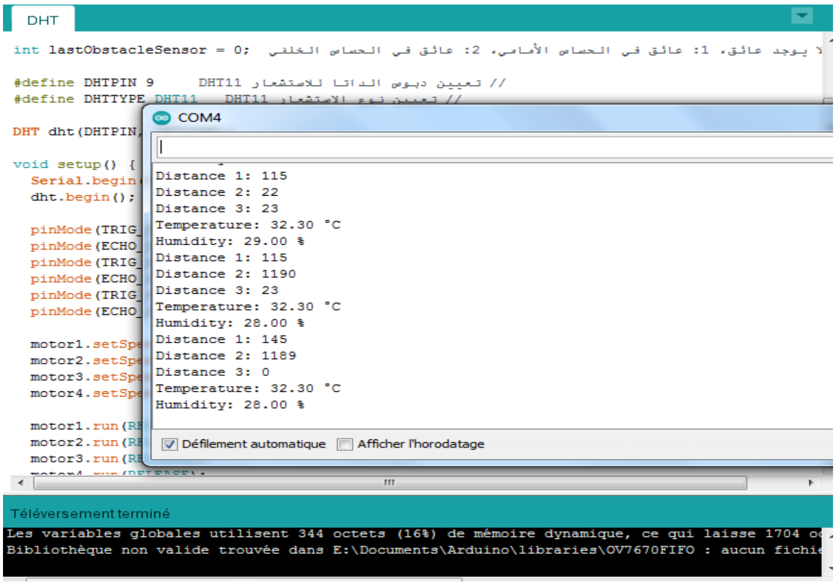


Figure 2-28 Moisture and Temperature Sensor Readings

2.4.2 Working

In this section, we will explore the detailed operational workflow of an automated system for plant disease detection and treatment. This includes the processes of collecting and analyzing data, detecting diseases, and applying treatments. Understanding how the system works in practice helps clarify the integration and coordination between its various components, ensuring timely and effective disease management.

• Our primary users of this platform are farmers.

• Engaging pesticide suppliers will expand our potential customer base.

• The presence of plants is checked using HC-SR04 ultrasonic sensors located on the lower support beam and the wheel movement is stopped by programmed instructions.

• When the action stops, the servo motor is activated, which is connected to a rod holding the camera, and rotates a full 180 degrees to capture images from different angles.

• The camera is set to take pictures at specific time intervals, focusing on damaged parts or leaves of plants.

• These images are transferred to the Raspberry pi5 over the IOT network using the MQTT protocol

• Images taken of diseased leaves are compared with reference images stored in the Raspberry Pi. Once the analysis is complete, the user receives a detailed report suggesting the appropriate pesticides, their usage and chemical composition, making it easier for the user to take proper care of their plants.

• For further enhancement, we will include a team of experts to study the images and provide solutions to the affected plants after a comprehensive analysis.

• To begin with, the robot provides the ability to apply pesticides to tomato plants. It carries the pesticide in a tank and sprays it on the affected area of the crop through a pump mechanism equipped with nozzles connected to the end of the robot.

• The pesticide spraying device automatically sprays the appropriate pesticides when it detects infected leaves.[32]

Thus, a prototype of the project was created, designed simply to overcome the basic challenges. This marked the beginning of its development journey as shown in Figure 2-29.

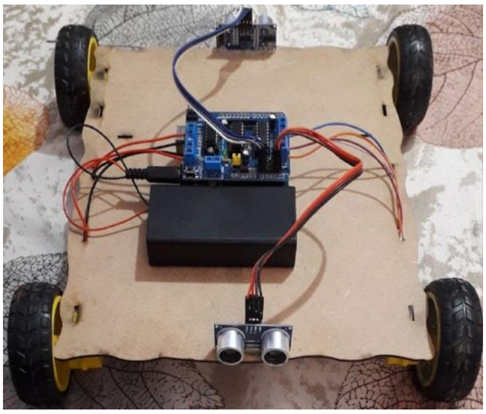


Figure 2-29 First Designed Prototype

2.4.3 Design Innovation

2.4.3.1 Artificial Intelligence for Plant Disease Detection:

- Utilizing AI algorithms to accurately diagnose plant diseases.
- Predicting potential disease outbreaks based on environmental and climatic data using AI.

2.4.3.2 Autonomous Robot:

- Continuous monitoring of plant health using sensors and cameras.
- Automated disease treatment with pesticides or liquid nutrients upon detection.

- Prediction of future disease outbreaks using forecasting models.

2.4.3.3 Android Application:

- AI-powered mobile app enabling farmers to diagnose plant diseases directly via smartphones.
- Providing recommendations based on input data and AI-generated predictions.

2.4.3.4 Electronic Platform:

- Online platform for remote plant disease detection and prediction.
- Tools for data analysis and disease management from anywhere.

2.4.3.5 Precision Location Mapping:

- Accurate mapping of disease spread and creation of interactive maps showing affected areas.
- Early detection facilitating prompt intervention and containment.

2.4.3.6 Efficiency:

- Reducing manual monitoring efforts, saving time and resources.
- Minimizing treatment costs through early intervention and targeted resource use.

2.5 Conclusion

In this chapter, we discuss the design of an automated system to detect and treat plant diseases for farmers. The system uses a Raspberry Pi Camera Module 5 mounted on a servo motor to capture images from multiple angles, and uses ultrasonic sensors to detect obstacles and ensure smooth operation with the Johnson motor. The images are sent to a computer for analysis and identification of diseases, and a report is generated suggesting treatments and pesticides. The system includes an expert panel for additional analyzes and solutions, and an automatic pesticide spraying mechanism. It integrates moisture and temperature sensors to provide real-time data to growers, helping maintain optimal growing conditions. The model combines advanced technology with practical applications to support farmers in increasing productivity.

Chapter 3:

IMPLIMENTATION

Chapter 3

IMPLIMENTATION

3.1 Introduction

In this chapter, we present the practical steps taken to develop the "AGROBOT" system for diagnosing and treating plant diseases using deep learning. The implementation involves integrating various hardware and software components, including the Raspberry Pi Camera Module 5, sensors for humidity and temperature, and servo motors for precise movement.

We will discuss the integration of deep learning models, image processing, and the user interface for farmers. Key challenges and solutions during the development process will also be highlighted.

3.2 Process of Building the Mobile Robot

3.2.1 Hardware Implementation for AGROBOT

In mid-to-late January 2024, we initially began working on developing an early prototype, mostly related to the development of hardware (see Figure 3-1) and to a lesser extent, software. This culminated in the presentation of a short demo video in early February 2024. Initially, in late December 2023, we purchased some components through Facebook pages and electronics stores, and others were provided by the university.

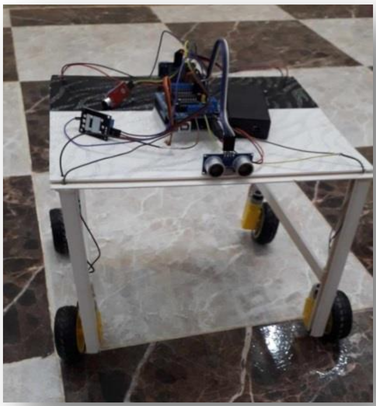


Figure 3-1 AGROBOT mobile robot in the early development stage

The complete hardware setup is mounted on a custom quadruped mobile platform, utilizing both Raspberry Pi and Arduino Uno for control, and webcam was used to capture images for analysis. Arduino Uno handles all other sensors and motor controls, including a GPS module for precise location tracking. It also manages two 12V DC motors, controlled by a DC motor driver shield receiving PWM signals for precise motor control. Power is supplied by a 3.7V 8800mAh Li-ion battery. For navigation and field row detection, two HC-SR04 ultrasonic sensors are used, along with an additional bottom-mounted ultrasonic sensor for plant detection. A humidity and temperature sensor monitors conditions inside the plastic greenhouse. Bluetooth connectivity is integrated for remote control and data transmission as illustrated in Figure 3-2.

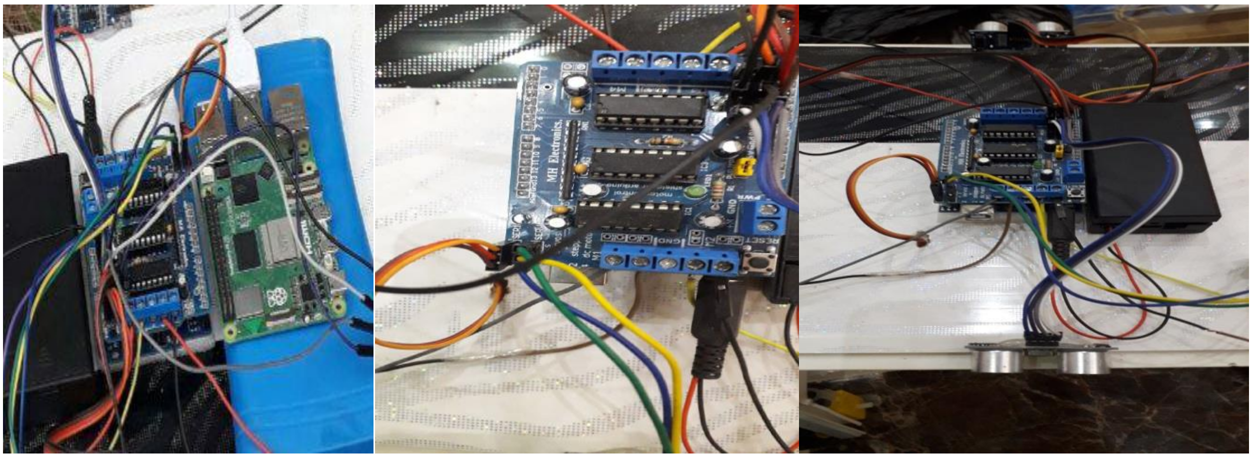


Figure 3-2 Wire connections in the middle base level

Our custom robot integrates the general mobile robot controller. Additionally, at the bottom, we've incorporated the Webcam for vision tasks and a GPS module for precise location tracking. All wiring connections were implemented using the detailed instructional manuals provided in the product kits tailored to our specific project requirements according to Figure 3-3.

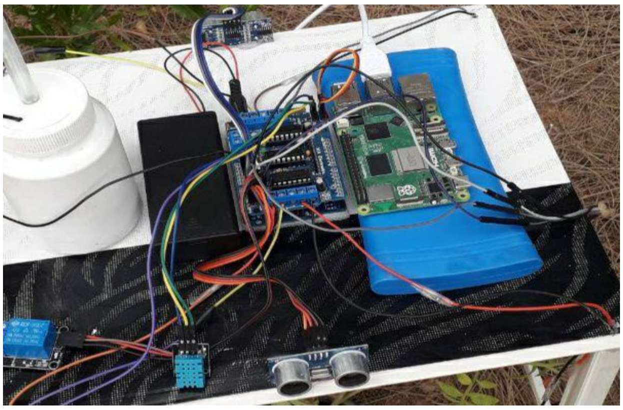


Figure 3-3 Bird's-eye view of the wiring connections on the bottom base level

The hardware architecture of our custom robot platform is demonstrated in Figure 3-4

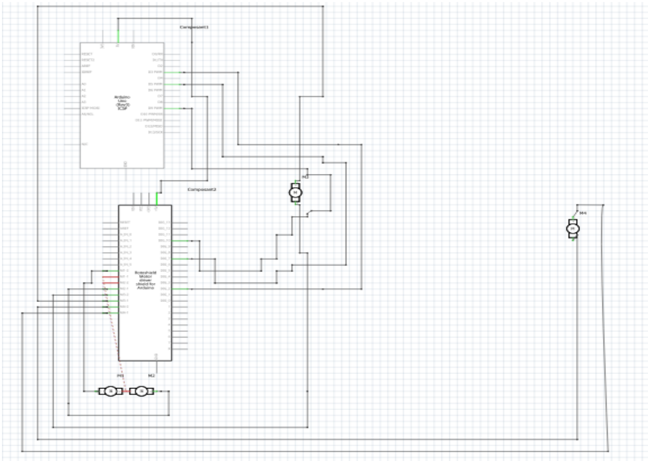


Figure 3-4 Hardware Architecture of the Mobile Robot Platform

The wiring connections between the general mobile robot controller, motors, and motor drivers are visually illustrated in the diagram in my project as depicted in Figure 3-5.

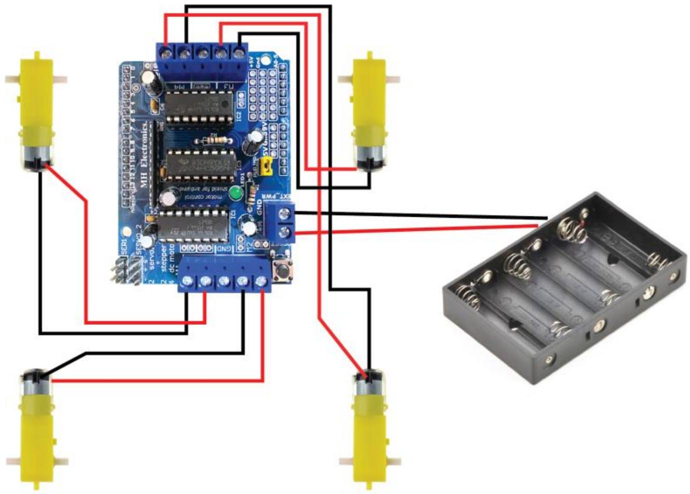


Figure 3-5 Wiring connections between controller, motors, and motor driver.

A webcam is mounted underneath the robot as part of the monitoring and imaging system. This webcam captures high-resolution images of plants and targeted areas in the field (see Figure 3-6). The system is designed to enhance monitoring and control capabilities with greater precision for various plant conditions.

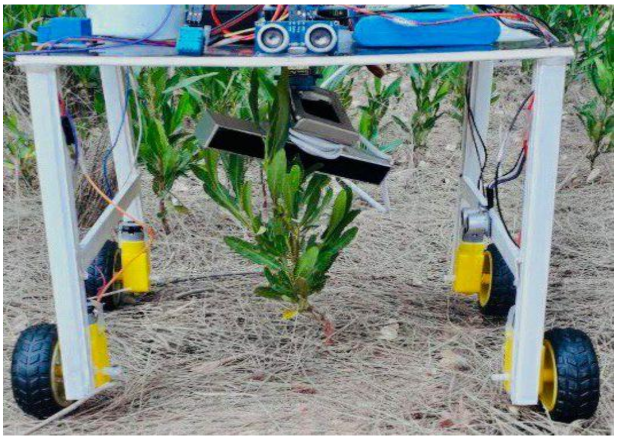


Figure 3-6 The webcam machine vision sensor is placed at the bottom

Shows the exact location and orientation of the camera module beneath the robot chassis based on Figure 3-7.

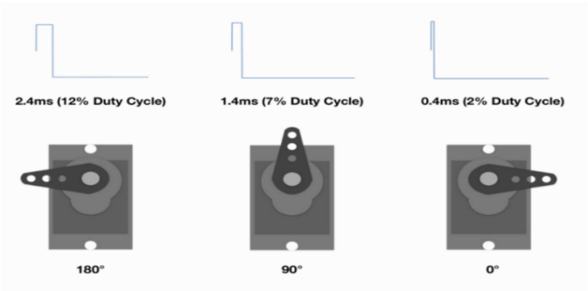


Figure 3-7 Physical Placement Diagram for Camera Movement

The following figure 3-8 shows how to connect the camera module to Camera web for image processing and data transfer.

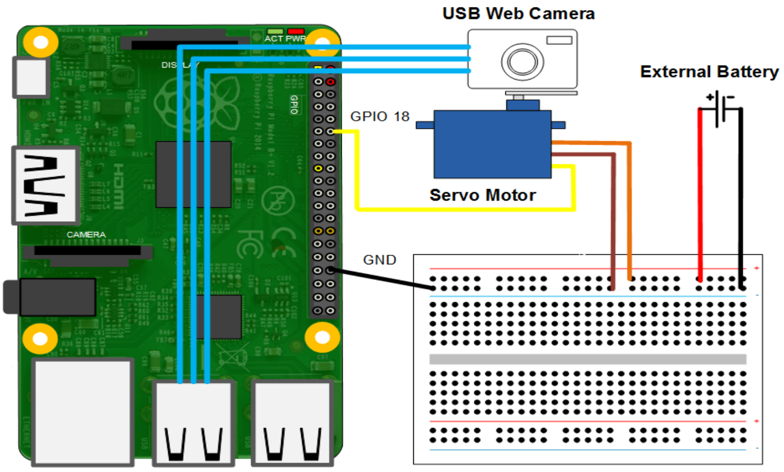


Figure 3-8 Camera Module Connection Diagram

The robot is equipped with three ultrasonic sensors to enhance navigation and functionality. The first sensor is located at the front of the robot and detects obstacles, determining when the robot should stop moving forward. The second sensor is at the back of the robot, helping to detect obstacles behind the robot and ensuring safe backward movement. The third sensor is mounted underneath the robot and detects the presence of plants directly below, aiding in precise positioning for plant inspection and treatment.

The following image illustrates the ultrasonic sensors located at the front and rear of the robot (see Figure 3-9)

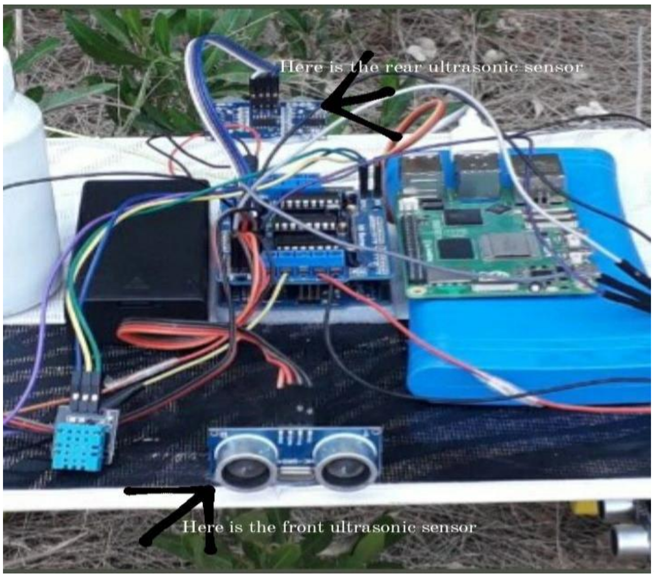


Figure 3-9 Front and Rear Ultrasonic Sensors Setup

Here is the sensor located underneath the robot ensuring plant detection as shown in Figure 3-10.

Figure 3-10 The bottom sensor for plant detection

The results from the front and rear ultrasonic sensors are displayed on the Serial Monitor in the Arduino IDE (see Figure 3-11). This allows for real-time monitoring of sensor readings, ensuring the robot's navigation system is functioning correctly. When the distance from an obstacle is less than 30 cm, the robot will take appropriate action to avoid collision.

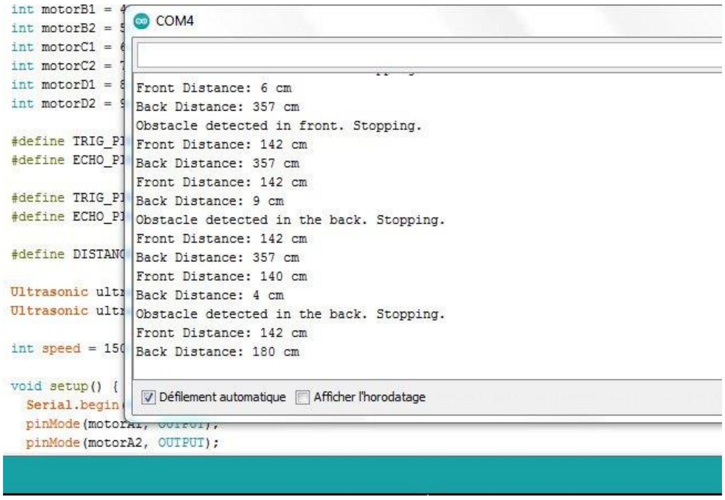


Figure 3-11 Monitoring Results in Arduino IDE

Each plant in the crop is individually sprayed with fertilizers and pesticides by AGROBOT. A liquid spraying device, made from a DC pump in a plastic tank, and controlled by a relay, is used to perform the spraying operation in the implemented design, as shown in Figure 3-12. The relay allows the Arduino to turn the pump on and off. The spraying system is designed to deliver only the specific amount of fertilizers and pesticides that each plant needs, reducing waste and achieving precision agriculture.

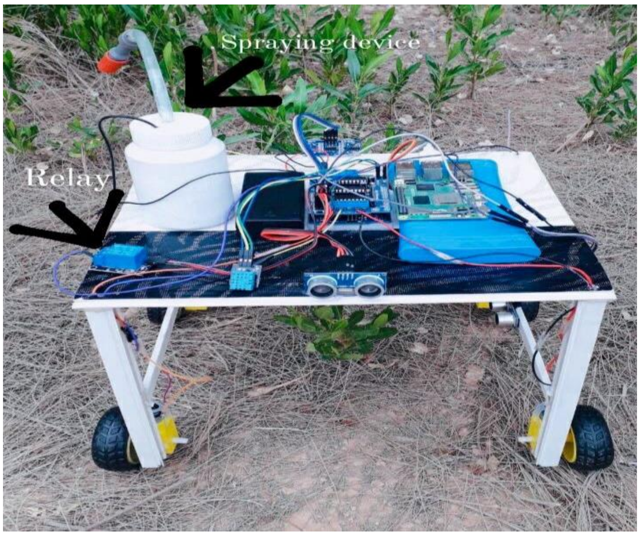


Figure 3-12 The implemented AGROBOT spraying mechanism

The Implemented AGROBOT: Designed using Raspberry Pi and Arduino Uno, this robot executes a wide range of agricultural tasks with precision. It features a liquid spraying system powered by a direct current pump connected to a plastic tank, ensuring precise and efficient delivery of fertilizers and pesticides. The design also incorporates multiple sensor systems including ultrasonic and thermal sensors for monitoring plant health and detecting potential diseases.

Moreover, the robot boasts advanced vision systems utilizing a high-definition camera for image analysis and plant condition assessment. It is also designed for precision farming by adjusting its height to accommodate various plant types and individual care requirements.

The Figure 3-13 show the robot operating within the farm, diagnosing plants using its onboard camera and applying targeted fertilizer spraying in case of diseases.

Figure 3-13 AGROBOT prototype

3.1.2 Software Implementation for AGROBOT

We tested the trained model and the results were as shown in Figure 3-14 :

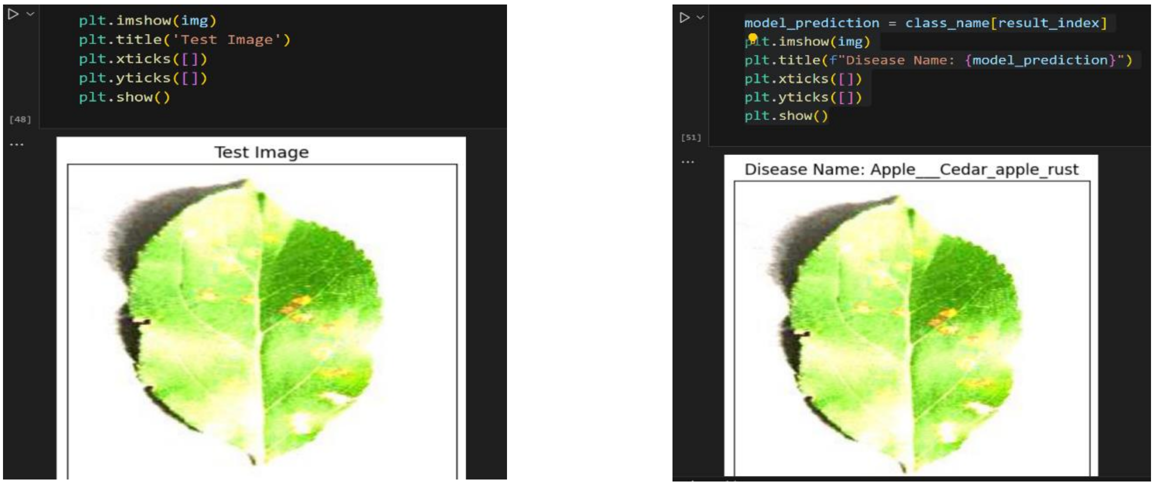


Figure 3-14 Test of the train model

We converted the trained artificial intelligence model into an Android application (Android), which the farmer can use manually with ease on his mobile phone directly on the plants as illustrated in Figure 3-15.

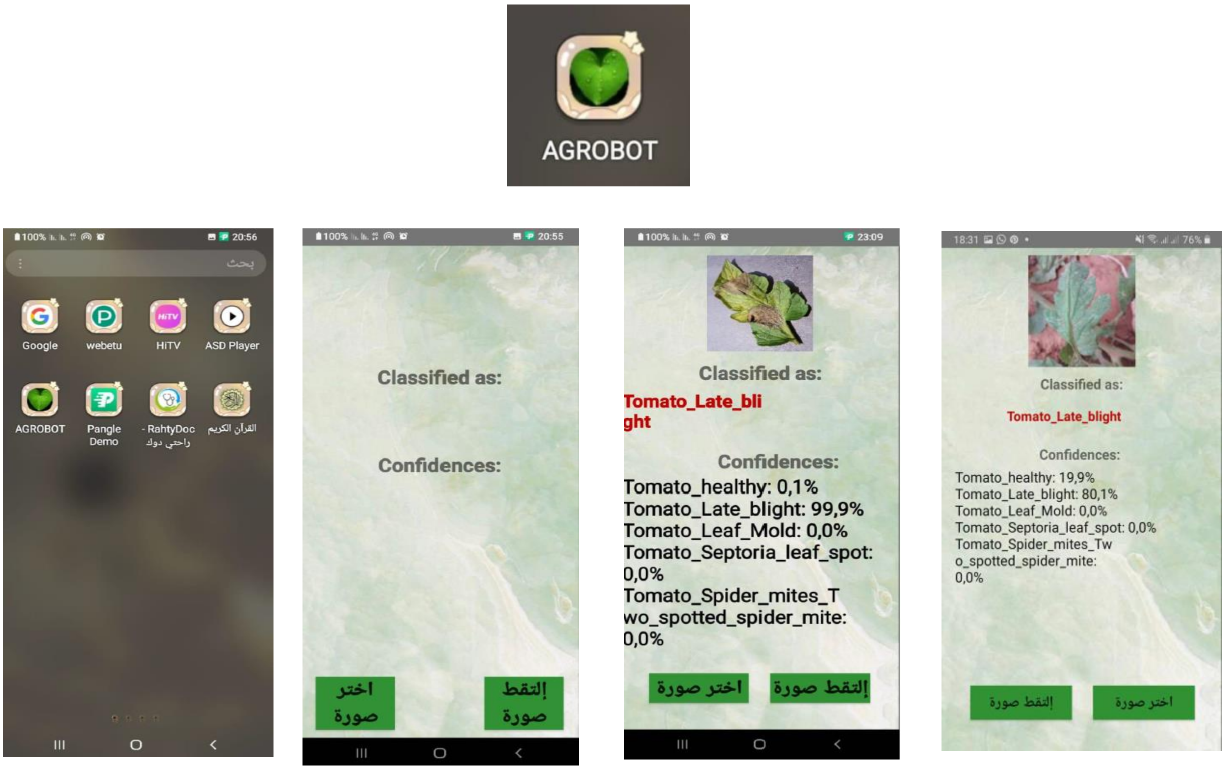
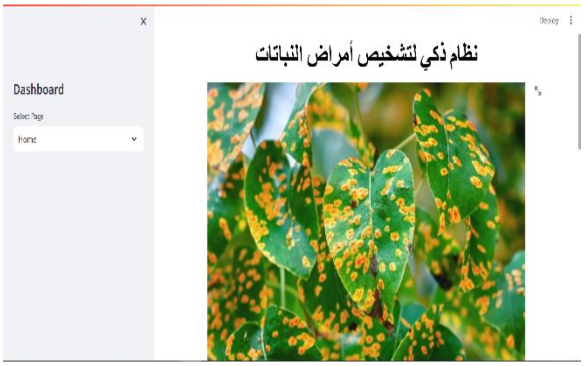
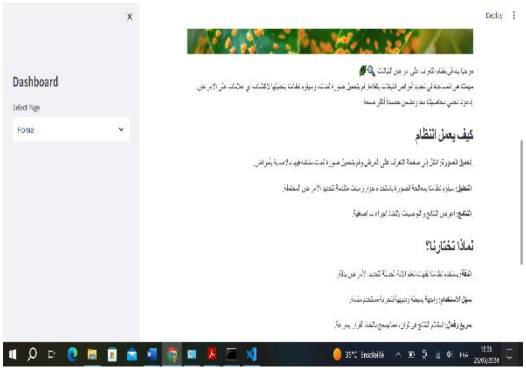
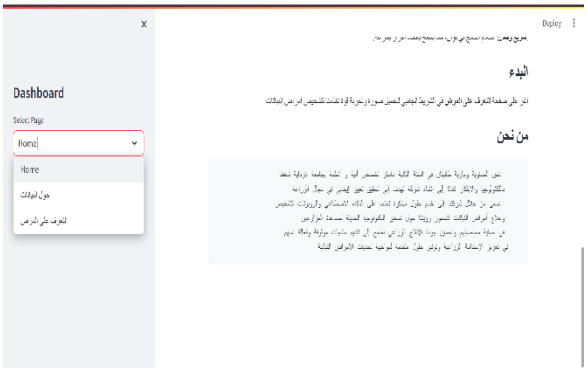


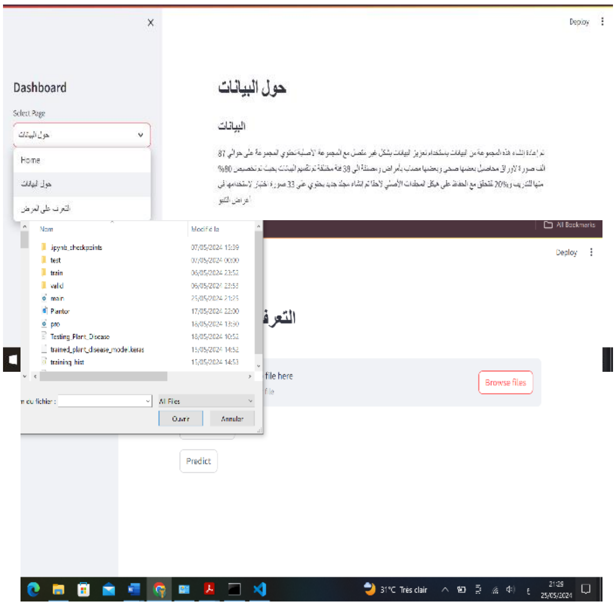
Figure 3-15 Android App (AGROBOT)

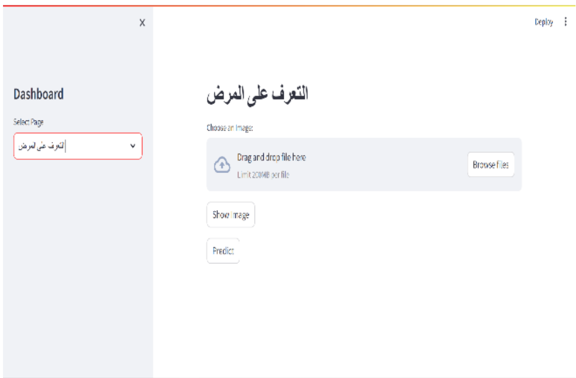
We converted the trained artificial intelligence model into a platform (web page), where the farmer or others can use it via the platform remotely according to Figure 3-16.

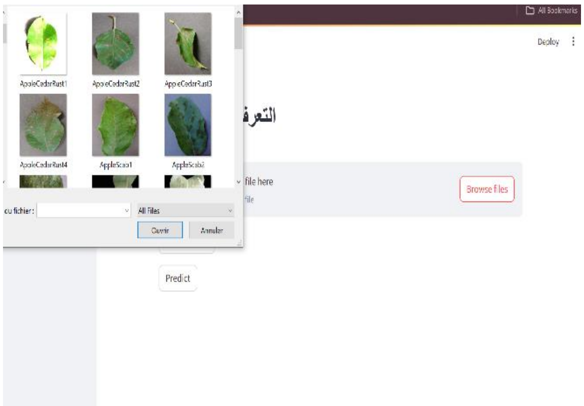


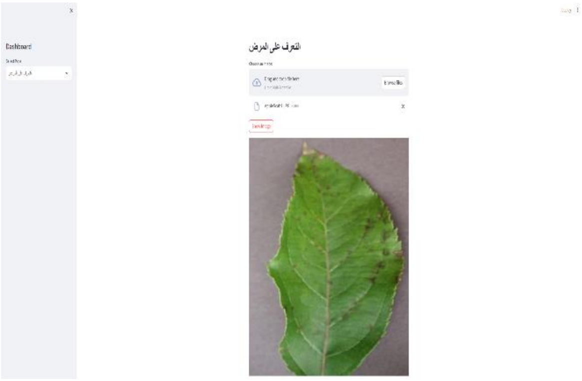












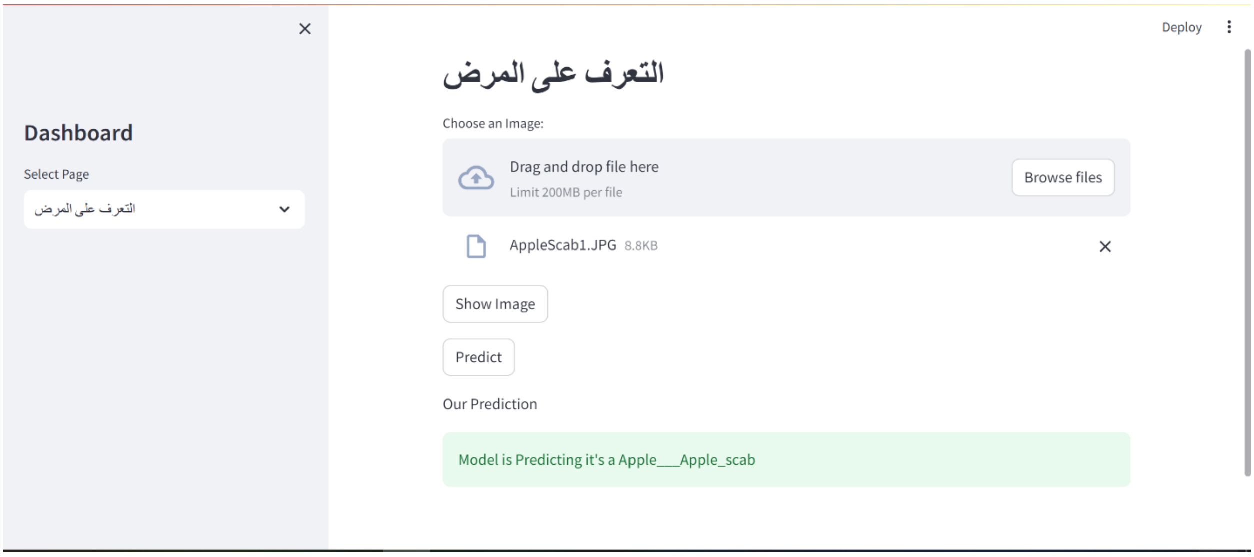


Figure 3-16 Platform for detecting plant diseases.

3.3 Artificial Intelligence

AI is a technology designed to replicate human intelligence and problem-solving capabilities using computers and machines. It can operate independently or in conjunction with other technologies like sensors, geolocation, and robotics, performing tasks traditionally requiring human intervention. Examples include digital assistants, GPS navigation, autonomous vehicles, and generative AI tools such as ChatGPT by OpenAI. Within computer science, AI encompasses machine learning and deep learning, where algorithms emulate human decision-making processes, enabling them to learn from data and improve predictions over time. Despite various hype cycles, AI's recent advancements, notably exemplified by ChatGPT, mark a significant shift, particularly in natural language processing (NLP). Modern generative AI can now comprehend and generate diverse data forms beyond language, encompassing images, video, code, and molecular structures. As AI applications expand across industries, discussions on AI ethics and responsible deployment are increasingly critical.[33]

3.3.1 Artificial intelligence in agriculture

The global population is projected to reach nearly 10 billion by 2050, as reported by the FAO. This growth necessitates new agricultural practices to meet rising food demands. Digital technologies, particularly artificial intelligence (AI), are pivotal in enhancing agricultural productivity and efficiency. AI innovations contribute by optimizing tasks such as planting and harvesting, reducing labor costs and time, and improving overall crop management. These advancements address food insecurity by boosting productivity and resilience in agriculture. AI's impact spans agricultural robotics, soil and crop monitoring, and predictive analytics, pivotal in sustainable food production amidst challenges like climate change and resource depletion.[34]

3.3.2 Artificial intelligence in diagnosing plant diseases

3.3.2.1 Dataset

We trained the AI using deep learning on 87,000 RGB images of healthy and diseased plant leaves that were classified into 38 different categories. Your dataset is split 80/20 from the training and validation set while preserving the underlying evidence. A new content guide is created on 33 images that are later tested to be predicted, the dataset shown in Table 3-1.[35]

Table 3-1 Dataset Specification

Plant	Disease Name	Number of images
Apple	Healthy Diseased Scab Diseased: Black rot Diseased: Cedar apple rust	2008 2016 1987 1760
Corn	Healthy Diseased: Cercospora leaf spot Diseased: Common rust Diseased: Northern Leaf Blight	1859 1642 1907 1908
Grapes	Healthy Diseased: Black rot Diseased: Esca (Black Measles) Diseased: Leaf blight (Isariopsis)	1692 1888 1920 1722
Potato	Healthy Diseased: Early blight Diseased: Late blight	1824 1939 1939
Tomato	Healthy Diseased: Bacterial spot Diseased: Early blight Diseased: Late blight Diseased: Leaf Mold Diseased: Septoria leaf spot Diseased: Two-spotted spider mite Diseased: Target Spot Diseased: Yellow Leaf Curl Virus Diseased: Tomato mosaic virus	1926 1702 1920 1851 1882 1745 1741 1827 1961 1790

These are some samples from our dataset shown in 3- 14

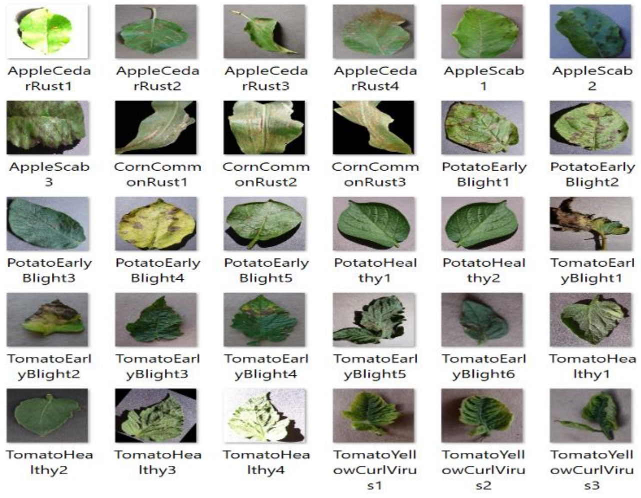


Figure 3-17 Sample images in dataset

3.3.2.2 Training ResNet50 for Plant Disease Classification

Plant leaf image datasets were loaded and processed using TensorFlow, specifying image size and color modes. A ResNet50 model pre-trained with ImageNet weights was used to extract features from images. Additional layers have been added to the model to improve feature learning, including the use of GlobalAveragePooling2D and conjoined layers with the ReLU activation function to improve predictive performance. The model was trained using training and validation data over several training runs, with tools such as early stopping. The model was then used to predict plant diseases, and extract important features such as structure, color and texture from images (see Figure 3-18). Image analysis using these features has been improved to achieve higher accuracy in classification and prediction of plant diseases .

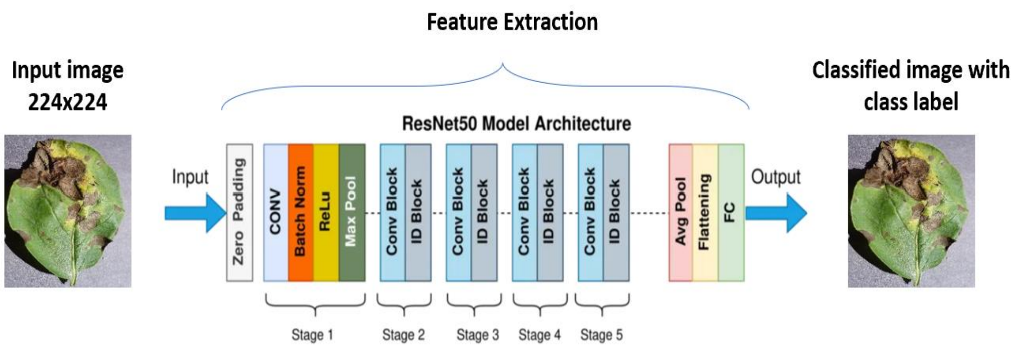


Figure 3-18 Steps for Training ResNet50.

3.3.2.3 Performance Evaluation of ResNet50

Th figure 3-19 shows a comprehensive evaluation of the performance of ResNet50 model in predicting plant diseases.

	precision	recall	f1-score	support
Apple___Apple_scab	0.98	0.98	0.98	504
Apple___Black_rot	0.96	0.99	0.98	497
Apple___Cedar_apple_rust	0.99	0.99	0.99	440
Apple___healthy	0.96	0.98	0.97	502
Blueberry___healthy	1.00	0.99	0.99	454
Cherry_(including_sour)___Powdery_mildew	1.00	0.99	1.00	421
Cherry_(including_sour)___healthy	0.99	1.00	0.99	456
Corn_(maize)___Cercospora_leaf_spot Gray_leaf_spot	0.97	0.92	0.95	410
Corn_(maize)___Common_rust_	1.00	1.00	1.00	477
Corn_(maize)___Northern_Leaf_Blight	0.94	0.98	0.96	477
Corn_(maize)___healthy	1.00	1.00	1.00	465
Grape___Black_rot	0.94	0.98	0.96	472
Grape___Esca_(Black_Measles)	0.98	0.93	0.95	480
Grape___Leaf_blight_(Isariopsis_Leaf_Spot)	1.00	1.00	1.00	430
Grape___healthy	1.00	0.99	0.99	423
Orange___Haunglongbing_(Citrus_greening)	1.00	1.00	1.00	503
Peach___Bacterial_spot	0.99	0.99	0.99	459
Peach___healthy	0.99	0.99	0.99	432
Pepper,_bell___Bacterial_spot	0.97	0.99	0.98	478
Pepper,_bell___healthy	0.99	0.98	0.98	497
Potato___Early_blight	0.98	0.99	0.99	485
Potato___Late_blight	0.99	0.96	0.97	485
Potato___healthy	0.99	0.98	0.98	456

Figure 3-19 Performance of ResNet50.

3.4 Conclusion

In this chapter we talk about how we made our own robot, from building hardware to building software, what AI brings to agriculture, and how we use AI to detect plant diseases.

Chapter 4:

NAVIGATION OF AGROBOT

4.1 Introduction

4.1.1 Definition of navigation in robots

Navigation is defined in Encyclopedia Britannica as the science of guiding a vehicle by determining its location, path, and distance traveled. Mobility aims to reach the desired destination, avoid collisions, save fuel, and adhere to schedules. For a mobile robot, mobility is the ability to move from one place to another in an organized manner. Although the main goal of a mobility robot is to reach a destination, it must be able to perform specific tasks to solve real-world problems, such as a gardening robot trimming trees, a delivery robot transporting mail or groceries, and a monitoring robot reporting monitoring results. Navigation is the fundamental ability that enables a robot to perform these tasks efficiently.[36]

4.1.2 The importance of navigation in agricultural robots

It is a guide in the necessary preparations of necessity as shown in everything and productivity, as it establishes effective and precise responsibility within limits, which limits the time for its commitment and enhances safety by avoiding commitment to the safety of robots and workers. In addition, intelligent routing helps adapt to small changing conditions, collects data on the condition of vegetables and soil, which contributes to adaptation management and reduces operational costs. It also supports the global mathematics network by reducing the use of giant chemicals, resulting from farming practices and profit from investment in the field of investment.[37]

4.1.3 Challenges of navigation in agricultural environments

- Unexpected desires
- Changing environmental conditions
- Accuracy in positioning
- Interaction with other plants
- Knowing its causes
- Adapt to diverse options
- Cost and technological complexity

4.2 Navigation Techniques

4.2.1 Sensors

Relies on the use of a variety of sensors to precisely locate and guide the robot within the agricultural environment. Sensors play a vital role in collecting and analyzing environmental data to make accurate steering decisions. Below are the types of sensors:

- Camera: is used to see the surrounding environment and recognize objects such as plants, barriers, and equipment, which helps in determining appropriate paths and moving between them, in addition to recognizing the condition of plants based on their colors to identify disease areas as shown in Figure 4-1.

Figure 4-1 Navigation using Camera

- LIDAR: is used to measure distances with high accuracy, create three-dimensional maps of the surrounding environment, identify obstacles in the robot's path to avoid them effectively, and provide accurate data about distances and angles, which enhances guidance accuracy as illustrated in Figure 4-2.

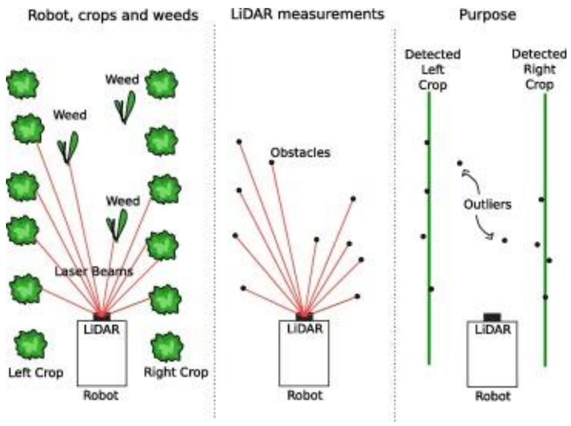


Figure 4-2 Navigation using LIDAR

- Ultrasonic sensors: emit sound waves to measure distances through the reverberation time of these waves. They are effective in detecting nearby obstacles that may not be visible by cameras or lidar. They are considered a less expensive alternative compared to some other types of sensors while providing good performance in avoiding obstacles according to Figure 4-3.

Figure 4-3 Navigation using ultrasonic sensor

- GPS: This technology relies on satellites to provide accurate data about the geographical location of the agricultural robot and guide its movement. The system components include a GPS receiver, a control system, and guidance software that includes path planning algorithms. GPS-based orientation provides many benefits, including high accuracy in determining locations, increasing productivity by improving agricultural processes such as precision farming, irrigation, and harvesting, saving time and effort, and enabling robots to work independently without the need for continuous human intervention as depicted in Figure 4-4.

Figure 4-4 Navigation using GPS

4.2.2 Maps

In agricultural robots depends on the use of different types of maps to determine the paths of robots and guide them accurately. Two-dimensional maps are used to provide a flat representation of the agricultural environment, showing the relative locations of obstacles and various landmarks such as trees, stones, and agricultural equipment, while three-dimensional maps provide A three-dimensional representation that includes details of elevation and terrain, which helps robots navigate complex terrain. We obtain these maps through a group of sensors such as lidar, cameras, and ultrasonic sensors to collect data about the surrounding environment, and then this data is used to create a detailed map representing the agricultural environment. Because the agricultural environment is constantly changing due to plant growth, seasonal changes, and various agricultural operations, it is necessary to update maps regularly to reflect new changes.

4.2.3 Computer vision

For analyze visual data such as images and video to accurately determine and guide the robot's paths within the agricultural environment. These technologies are used to detect and identify environmental features such as plants, barriers, and agricultural equipment, which helps the robot determine safe and appropriate paths for navigation. Images and video are analyzed in real time to allow the robot to make quick and accurate decisions about steering, and the robot can adjust its path in real time based on the visual data received. . Machine learning techniques are used to improve the robot's ability to interpret visual data and adapt to changing conditions in the agricultural environment, allowing the robot to learn from its experience and improve guidance accuracy over time. This approach enhances the capabilities of agricultural robots to effectively navigate within fields, contributing to improved accuracy and efficiency in performing complex agricultural tasks.

4.3 Navigation Algorithms

4.3.1 Traditional algorithms

Dijkstra's algorithm stands out as a leading method for pathfinding and obstacle avoidance, it operates within a graph framework to find the shortest route from a designated source node to all other nodes depicted in Figure 4.5.

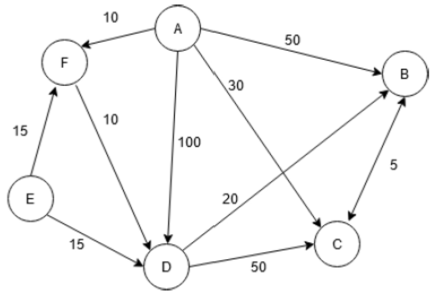


Figure 4-5 Example of the standard graphical form of Dijkstra's algorithm

When addressing optimal pathfinding solutions, algorithms must proficiently manage three scenarios: firstly, when an optimal route is feasible; secondly, when no optimal path exists; and thirdly, when an optimal path is available simply due to its unbounded length. The primary benefit of Dijkstra's algorithm lies in its capacity to pinpoint the most economical path to all nodes labeled permanently within the graph. Moreover, unlike human users, it does not necessitate a fresh diagram for each pass and the algorithm has an order of n2, rendering it advantageous for moderately sizable problem sets. Nonetheless, its blind search approach can be resource-intensive and time-consuming. Furthermore, the algorithm falters in handling negative edges, resulting in non-cyclic graphs that often fail to identify the correct shortest path. To address these limitations, Dijkstra's algorithm has been enhanced through advancements in pathfinding algorithms, notably the widely acclaimed A* algorithm, renowned for its sophisticated capabilities in navigating paths and circumventing obstacles effectively.

4.3.2 Modern algorithms

include integrated techniques for efficient and accurate guidance operations in complex environments, and include reinforcement learning, technical networks, and key techniques. Reinforcement learning is based on the principle of reward and punishment to learn behavior in return. It uses an agent that interacts with its environment and seeks to achieve specific goals through trial and error. It can be applied to guidance in agricultural robots to learn controls and chooses and succeeds only on previous achievements. A technology company that relies on human neural network models to accurately analyze data and perform specific simulations, enabling robots to use computer data such as photographs and perceive the environment with high accuracy and guidance operations.

4.3.3 Comparison between traditional and modern algorithms

Modern algorithms represent a breakthrough in technology thanks to their ability to adapt and learn optimal behaviors on their own, which contributes to improving the accuracy and efficiency of guidance in complex environments. In general, modern routing algorithms reflect the great development in technology, compared to traditional algorithms that rely on fixed rules and need manual updating of environmental information.

4.4 Self-Location and Mapping (SLAM)

Is a concept in robotics that combines simultaneous self-localization and map building. It is crucial in enabling robots to accurately determine their location and construct detailed maps of the environment they navigate within.

The importance of SLAM in agricultural robotics lies in:

- Facilitating Smart Navigation: SLAM helps agricultural robots accurately pinpoint their locations while navigating fields, enabling them to map crops and treatment areas effectively.
- Enhancing Efficiency: With precise maps, agricultural robots can execute tasks more efficiently, leading to improved productivity and reduced costs.

Techniques and methods of SLAM include:

- LIDAR-based SLAM: Uses LIDAR to measure distances and spatial inference, allowing robots to build high-resolution 3D maps of the environment.
- Vision-based SLAM: Relies on cameras and visual sensors to determine locations and build maps based on visual landmarks in the environment.

SLAM represents a vital technology in agricultural applications, where robots deal with dynamic and complex environments, aiding in precise and efficient navigation within farms and fields, thereby enhancing resource utilization efficiency and improving agricultural production quality.

4.5 Avoiding Obstacles

Is critical for agricultural robots operating in complex environments. These environments pose various types of obstacles that can hinder the robot's movement and functionality. These obstacles include:

- Natural Obstacles: Such as plants, trees, rocks, and rugged areas that can obstruct the robot's path and require careful navigation.
- Man-Made Obstacles: Including fences, irrigation systems, and farm equipment that the robot needs to navigate around or between without causing damage or disruption.

❖ The techniques used for obstacle avoidance in agricultural robotics include:

- Immediate Sensing: Utilizing sensors such as proximity sensors, ultrasonic sensors, and infrared sensors to detect obstacles in real-time. These sensors provide immediate feedback to the robot's control system, allowing it to adjust its path or stop to avoid collisions.
- Path Planning: Pre-planning the robot's path using mapping and localization techniques (like SLAM) to anticipate obstacles and plan alternative routes. This approach helps in navigating efficiently and safely through the field.

❖ The examples of applications of obstacle avoidance in agricultural robots include:

- Crop Monitoring and Treatment: Robots equipped with sensors navigate between rows of crops, avoiding plants while monitoring growth and applying targeted treatments such as fertilizers or pesticides.
- Harvesting: Autonomous harvesting robots avoid damaging plants or fruit while navigating through orchards or fields, ensuring efficient collection without loss or damage.
- Autonomous Vehicles: Automated tractors or vehicles navigate through fields, avoiding obstacles such as irrigation equipment or natural terrain variations to perform tasks like plowing or seeding.

In summary, effective obstacle avoidance strategies in agricultural robotics are crucial for ensuring safe and efficient operation in challenging and dynamic farm environments, ultimately enhancing productivity and reducing operational costs.[38]

4.6 Integration of Orientation with Robot Tasks

The system relies on the use of advanced sensor systems that provide accurate data about the surrounding environment and the condition of plants. This data is analyzed using artificial intelligence and machine learning techniques, in order to make appropriate decisions that enhance the robot’s performance in carrying out various tasks. Artificial intelligence contributes to improving guidance by training prediction and classification models using big data, which enhances the robot’s ability to adapt to changes in different environments and make faster and more accurate decisions. This integration enhances the efficiency of AGROBOT performance in many diverse applications.

4.7 Conclusion

Orientation techniques based on sensors, maps and computer vision are the basis for navigation in agricultural robots. Traditional algorithms such as Dijkstra and modern algorithms such as reinforcement learning and deep neural networks contribute to improving guidance accuracy in complex agricultural environments. Advanced systems rely on real-time sensing technologies and advance route planning, as well as the use of artificial intelligence to analyze data and make appropriate decisions. Future challenges include adapting to sudden environmental changes and improving interaction with diverse infrastructure, while opportunities include improving production efficiency and reducing costs

Conclusion

In conclusion, our project represents a significant advancement in agricultural technology through the integration of artificial intelligence (AI), robotics, and deep learning for the diagnosis and treatment of plant diseases. Agriculture faces pressing challenges such as ensuring sustainable food production amid population growth and combating the detrimental impact of plant diseases on crop yield and global food security. Traditional methods of disease detection and management are labor-intensive, costly, and prone to errors, particularly in large agricultural settings. Our solution, AGROBOT, addresses these challenges by leveraging AI-powered robotics to autonomously identify and treat plant diseases with high accuracy and efficiency.

The AGROBOT initiative centers on a mobile robotic platform equipped with sophisticated sensors and AI algorithms capable of analyzing plant health in real-time. By integrating deep learning models trained on extensive datasets of plant diseases, the system can swiftly detect and classify diseases, enabling timely intervention and precise application of treatments. This capability not only enhances crop protection and productivity but also reduces reliance on chemical pesticides, promoting sustainable agricultural practices.

Looking ahead, our project envisions further enhancements and innovations to expand AGROBOT's capabilities. Future developments include enhancing machine learning models with more comprehensive datasets, integrating edge computing for real-time data processing, and improving the robot's robustness and adaptability to diverse environmental conditions. Collaborative research with agricultural experts will validate and refine disease diagnosis models, ensuring continual improvement and adaptation to evolving agricultural needs.

In summary, AGROBOT exemplifies the transformative potential of AI and robotics in agriculture, offering a scalable and sustainable solution to enhance food security, optimize resource utilization, and foster economic growth. By bridging technological innovation with agricultural efficiency, our project aims to empower farmers with advanced tools for managing plant health effectively in the face of global agricultural challenges.

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كلية العلوم والتكنولوجيا

قسم الآلية والكهروميكانيك

Université de Ghardaïa

غرداية في: 2024/09/15

إذن بالطباعة (مذكرة ماستر)

بعد الاطلاع على التصحيحات المطلوبة على محتوى المذكرة المنجزة من طرف الطلبة التالية أسماؤهم:

1. الطالب (ة): شرع الضاوية
2. الطالب (ة): أولاد هدار مارية

تخصص: آلية وأنظمة

تمنح نحن أعضاء لجنة المناقشة:

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الإذن بطباعة النسخة النهائية لمذكرة الماستر الموسومة بعنوان:

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إمضاء رئيس القسم