



AI-Based Agribot for Plant Disease Detection and Pesticide Spraying (Multipurpose)

Chiranth R

R.R. Institute of Technology, Bangalore, India

Shyamala P Bhat

R.R. Institute of Technology, Bangalore, India

K Lathangi

*R.R. Institute of Technology, Bangalore, India
lathalathangi98@gmail.com*

Bindu Shree G R

R.R. Institute of Technology, Bangalore, India

Kavya B M

R.R. Institute of Technology, Bangalore, India

Abstract: This paper presents an autonomous, AI-driven agricultural robot (Agribot) designed to automate multiple farm operations. The proposed system combines embedded hardware, artificial intelligence, and Internet of Things (IoT) technologies to provide an integrated solution for modern precision agriculture. The Agribot integrates computer vision and machine learning techniques to perform real-time plant disease and pest identification, triggering a targeted pesticide-spraying mechanism that minimizes chemical use and environmental impact. The disease identification module analyzes captured crop images to detect symptoms at an early stage, enabling timely intervention and reducing the spread of infections across the field. In addition, it monitors soil moisture and automatically irrigates when needed to maintain optimal growing conditions. The system is built around an Arduino Uno microcontroller with motor drivers, relays, and wireless communication modules. These components work together to provide reliable sensor data acquisition, actuator control, and seamless communication between the robot and the remote monitoring interface. It can operate autonomously following pre-programmed logic or be controlled remotely via a smartphone interface for real-time monitoring. The wireless monitoring capability enables farmers to supervise field operations, receive system updates, and intervene whenever necessary, thereby improving operational flexibility. The modular design emphasizes energy efficiency, scalability, and ease of use, making it a cost-effective solution for small to medium-sized farms. By automating key tasks—disease detection, precision spraying, soil sensing, irrigation, and navigation—the Agribot aims to enhance crop yields, lower labor requirements, and contribute to sustainable precision agriculture.

Keywords: Agricultural Robot, Iot, Computer Vision, Plant Disease Detection, Autonomous Farming, Sensor Integration.

Nomenclature

Abbreviation	Description
AI	Artificial Intelligence
CNN	Convolutional Neural Network
DC	Direct Current
GPS	Global Positioning System
IoT	Internet of Things
LCD	Liquid Crystal Display
PWM	Pulse Width Modulation
USB	Universal Serial Bus
TCP	Transmission Control Protocol
SPP	Serial Port Profile

1. Introduction

Modern agriculture is increasingly embracing automation to address labor shortages, rising costs, and efficiency demands [6][7]. Population growth and the increasing demand for food have made the adoption of advanced agricultural technologies essential for achieving higher productivity and sustainable resource management. In many regions, traditional farming practices such as manual sowing and spraying are time-consuming and physically demanding [1][2]. For example, conventional seed sowing often relies on animal-drawn funnels or manual drills, which are labor-intensive and expose workers to heat and fatigue. The emergence of autonomous field robots offers a way to mitigate these challenges by automating repetitive tasks and enabling remote operation under safer conditions. Agricultural robots are capable of performing repetitive field operations with improved accuracy, consistency, and operational efficiency, thereby reducing human intervention in hazardous environments. These robots leverage sensors, GPS, and wireless communications to navigate fields accurately and perform tasks faster and more reliably than manual labor. The rapid advancement of artificial intelligence (AI), embedded systems, and Internet of

Things (IoT) technologies has further accelerated the adoption of intelligent robotic platforms in agriculture [10][11][15]. These technologies enable continuous field monitoring, automated decision-making, and real-time responses to changing environmental conditions [11][14][15].

In the context of precision farming, automated systems are used to manage plants on an individual basis, optimizing inputs like seeds, water, and chemicals for each crop. Precision agriculture focuses on applying the right treatment at the right place and time, thereby maximizing crop productivity while minimizing resource wastage. This approach can significantly increase productivity and sustainability by reducing waste and ensuring healthy growth. Motivated by these advances, this project develops an AI-enabled Agribot capable of sensing and responding to field conditions. Specifically, the Agribot is designed to scan crops for disease or pest damage using an onboard camera and trained image classifier, then apply pesticide only where needed [8][9][13]. It also incorporates soil moisture sensors to trigger irrigation, ensuring each plant receives the right amount of water. Automated irrigation scheduling helps maintain optimum soil moisture levels while reducing unnecessary water consumption, making the system suitable for regions facing water scarcity. The integration of machine learning with computer vision enables the robot to recognize visible symptoms of plant diseases at an early stage, thereby supporting timely intervention before infections spread across the field.

The main objectives of this work are to integrate computer vision into an agricultural robot for real-time disease detection, implement a precision pesticide spraying mechanism, and add autonomous irrigation control based on soil moisture. The proposed framework integrates sensing, processing, decision-making, and actuation into a unified embedded system capable of autonomous field operation. All control functions run on a microcontroller that coordinates sensory inputs (camera, moisture, and environmental sensors) with actuators (motors for movement and digging, pumps for water and chemicals). The system can operate autonomously according to its internal logic or be monitored and controlled remotely through a smartphone application. This multi-functional Agribot is intended to reduce pesticide overuse, save labor, and improve crop yield, while remaining affordable for small- and medium-scale farms. Its low-cost hardware design and energy-efficient operation make it practical for deployment in resource-constrained agricultural environments. The proposed system adopts a modular architecture, allowing additional sensing devices and intelligent control modules to be incorporated with minimal hardware modifications.

2. Literature Survey

Recent research in agricultural robotics has explored many aspects of farm automation [6][7]. The increasing demand for precision agriculture has encouraged researchers to develop intelligent robotic systems capable of performing multiple farming operations with minimal human intervention. Several studies address the use of robots for planting and irrigation. For example, Sunitha et al. developed a robotic —seeding system to overcome labor shortages and rising costs in farming [1]. This work highlighted the potential of robotics to lessen farmers' workload by handling tasks like seed placement under varying field conditions. Their findings demonstrated that automated seeding mechanisms can improve planting accuracy and reduce the time required for field preparation compared with conventional methods.

Similarly, Priyadarshini and Sheela designed a multifunctional field robot that performs soil analysis, seeding, pesticide spraying, and even compost management [2]. Their research emphasized the importance of integrating multiple agricultural operations into a single robotic platform to improve field productivity and reduce equipment costs. Their system used mobile-phone tone signals (DTMF) to control robots remotely and coordinated two robots via wireless communication to carry out tasks such as digging and spraying. The implementation of wireless communication enhanced operational flexibility by enabling remote monitoring and synchronized task execution between robotic units. Another approach focused on navigation: Singh et al. built a remote-controlled agribot that plows and plants seeds at uniform intervals using GPS and wireless user interfaces [3]. In that design, an ultrasonic sensor enabled obstacle avoidance, and a stepper-driven seed dispenser precisely placed seeds in dug holes. Beyond planting and irrigation, automation of harvesting and field coverage has also been studied. Harvest automation has gained significant attention because it addresses seasonal labor shortages and improves harvesting efficiency without compromising crop quality. Firthous Begum and Vignesh developed a pick-and-place harvesting robot with wireless charging to reduce costs [4]. Their analysis showed that automating fruit picking could cut production costs by roughly 35–45%.

In path planning for mobile agricultural robots, Buniyamin et al. examined algorithms for static and dynamic environments [5]. Efficient path-planning algorithms are essential for ensuring complete field coverage, minimizing travel distance, and reducing energy consumption during autonomous operation. They emphasized the importance of choosing complete or heuristic path-planning strategies to avoid obstacles while navigating fields. Targeted pesticide application is an area of growing interest. Recent advancements in computer vision and machine learning have enabled intelligent spraying systems to

identify infected crops with greater accuracy and respond automatically to disease symptoms. Some research has proposed intelligent sprayers that use sensors to detect infected plants and apply chemicals only where necessary. For example, an autonomous robot for weed control in crop fields has been reported [6]. Such systems typically combine GPS or camera-based navigation with servo-driven spray nozzles and pumps. By linking the disease detection output to the spraying mechanism, these robots can minimize chemical usage.

In summary, prior work demonstrates the value of integrating sensors, AI, and automation in agriculture [12]. Although individual studies have successfully addressed specific agricultural tasks such as seeding, irrigation, navigation, harvesting, or spraying, most existing systems are designed for a limited set of operations. However, few systems combine all these functions into a single, low-cost platform. Our Agribot aims to unify disease detection, targeted spraying, soil sensing, irrigation, and navigation in one integrated system.

3. System Design

The design of the Android Streaming Micro Quadcopter with Obstacle Detection focuses on integrating a combination of manual control and autonomous features into a lightweight, modular system. The proposed architecture combines sensing, processing, communication, and flight control modules to provide reliable navigation and real-time environmental awareness. The modular design simplifies system integration and allows individual components to be upgraded or replaced without affecting the overall functionality of the quadcopter. The quadcopter is equipped with an Arduino Pro Mini [3], which processes data from an ultrasonic sensor (HC-SR04) to detect obstacles in its path. The sensor continuously measures the distance to objects in front of the drone by emitting ultrasonic pulses and calculating the time it takes for them to return. Distance measurements are updated in real time, enabling the system to respond quickly to nearby obstacles and improve navigation reliability. If an obstacle is detected within a predefined range, the Arduino [3] adjusts the flight path to avoid a collision, providing a layer of safety during manual piloting. Alongside this, the ESP32-CAM module is integrated to handle live video streaming. The onboard camera captures continuous visual information that enhances situational awareness during flight and supports remote surveillance applications. It uses its built-in Wi-Fi capabilities to create a local network, enabling any Android device to access a real-time video feed of the flight via a web browser—eliminating the need for a dedicated app. The wireless streaming mechanism provides low-latency video transmission, allowing users to monitor the drone's surroundings in real time without requiring additional communication hardware. This design enables users to monitor the drone's surroundings while piloting it without sacrificing system performance. Fig. 1 illustrates the overall architecture of the proposed Agribot.

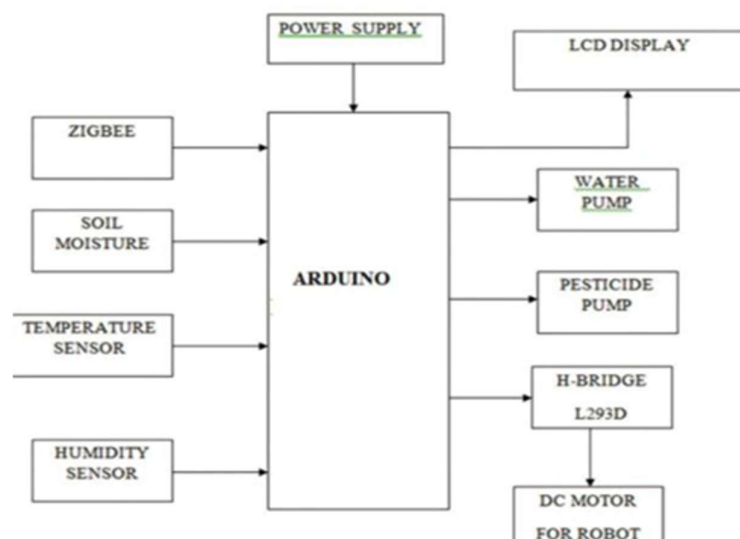


Fig.1. Block Diagram

4. Methodology

The Agribot's architecture blends sensing, computation, and actuation to perform its tasks autonomously. The proposed methodology integrates artificial intelligence, embedded systems, and sensor-based automation to perform multiple agricultural operations within a single robotic platform. Each subsystem

works collaboratively to ensure accurate monitoring, intelligent decision-making, and timely execution of farming tasks. The core processing unit is an Arduino Uno microcontroller, which executes the control program and interfaces with peripherals. The microcontroller continuously receives information from the connected sensors, processes the acquired data, and generates suitable control signals for the respective actuators. Fig. 1(illustrative)shows the overall system block diagram. The Agribot carries the following subsystems:

- **Vision and AI Module:** An onboard camera captures images of nearby plants. The captured images are continuously analyzed to monitor crop health during the robot's movement across the agricultural field. These images are fed into a pre-trained convolutional neural network (CNN) running on an embedded processor. Models such as MobileNet or VGG16 (trained on crop disease datasets) classify each plant as healthy or diseased. The trained deep learning model extracts important visual features such as leaf color, texture, and disease patterns to improve classification accuracy. The classification output is used to trigger the spraying mechanism if needed. This allows real-time, on-the-fly disease detection.
- **Soil Sensing and Irrigation:** A soil moisture sensor continuously monitors water content. The sensor periodically transmits moisture measurements to the Arduino, enabling continuous assessment of soil conditions throughout the cultivation area. The Arduino reads this sensor and compares the moisture level to a preset threshold. If the soil is dry, the system activates a water pump connected to a sprinkler or drip line. This ensures plants are watered only when necessary, conserving water. The automated irrigation process prevents both under-watering and over-watering, thereby supporting healthy plant growth while improving water-use efficiency.
- **Pesticide Spraying System:** A peristaltic or diaphragm pump is filled with pesticide solution, and its flow is controlled by a relay or solenoid valve. The spraying unit is designed to deliver a controlled quantity of pesticide directly onto the infected region, thereby avoiding unnecessary chemical application. When the AI module identifies a diseased plant, the Arduino powers the spray pump for a short duration to apply pesticide directly to that plant. This targeted spraying reduces chemical usage and limits exposure of healthy crops.
- **Mobility and Digging Mechanism:** The robot is mounted on a wheeled chassis driven by DC motors. The wheeled platform enables smooth movement across agricultural fields while maintaining sufficient stability during sensing and spraying operations. An H-bridge motor driver (e.g., L293D) is used to control the wheels. The Arduino also controls an onboard digging tool (attached to a motor) and a seed hopper mechanism. If the planting function is engaged, the robot stops at each plant location, lowers the digger to make a hole of appropriate depth, drops a seed from the hopper, and uses a leveler to cover the seed. This replicates the seed-sowing process in a precise manner.
- **Power and Communication:** A rechargeable battery pack powers the system. A voltage regulator ensures stable 5V for logic circuits. A Wi-Fi or Zigbee module is connected to the Arduino to enable wireless communication with a remote interface. An Android smartphone acts as a user interface: it receives real-time data (moisture level, plant status, battery level, etc.) and can also send control commands or parameters (such as moisture threshold) back to the robot.
- **Other Components:** Additional sensors measure ambient temperature and humidity to provide context for plant health monitoring. These environmental parameters assist in understanding crop growth conditions and support more informed agricultural decision-making. An LCD can be included to show status locally. Relays are used to switch the high-power pump and motors under microcontroller control.

The system logic is implemented as follows(see flowchart in Fig. 2 forreference). Upon power-up, the Agribot initializes all sensors and the camera. It then enters a loop where it:

1. **Measure environment:** Read soil moisture, temperature, and humidity.
2. **Disease detection:** Capture a plant image and process it through the CNN model. Classify the plant as healthy or diseased.
3. **Decide action:** If a disease is detected, activate the pesticide pump to spray the affected plant (e.g., for a fixed duration), then log this event.
 - Independently, check if soil moisture is below threshold. If so, activate the water pump to irrigate the immediate area around the plant.
4. **Digging and seeding (if in planting mode):** If the robot is performing seeding, activate the digging tool to create a hole at the plant's position, dispense a seed from the hopper, and use the leveler to cover it with soil.
5. **Navigation:** After completing actions at one plant, the robot moves to the next plant location. Navigation can be based on preset waypoints, line-following sensors, or simple dead reckoning using

wheel encoders.

6. **Repeat:** The loop continues for each plant or until the field is covered.

This methodology ensures the Agribot can autonomously perform monitoring and intervention tasks on-the-fly. The integration of AI-based vision with conventional sensors allows smart decision-making (spray only diseased plants, water only when needed). The logic is implemented in embedded C/C++ on the Arduino, with efficient routines for image capture and communication. The proposed methodology provides an intelligent, scalable, and energy-efficient solution for precision agriculture by integrating real-time sensing, automated control, and AI-driven decision-making into a unified agricultural robotic platform.

5. Implementation

The Agribot prototype was constructed with off-the-shelf components arranged on a mobile platform. The implementation focuses on developing a low-cost, reliable, and modular robotic system capable of performing multiple agricultural operations under real field conditions. The main hardware elements are summarized below:

- **Microcontroller:** An Arduino Uno serves as the central controller (ATmega328P). The Arduino coordinates all system operations by continuously monitoring sensor inputs and generating corresponding control signals for the connected actuators. It runs the main program loop, reads sensor values (via analog inputs), and controls actuators.
- **Camera and AI Processor:** A USB or serial camera module is mounted on the front. The camera is positioned to continuously capture images of crops during the robot's movement through the field, ensuring effective visual monitoring of plant health. For simplicity, the CNN model (MobileNet) may run on an attached single-board computer or on the Arduino if a lightweight model is used. In prototype form, the camera feed could be transmitted to the smartphone for processing, or a local microcomputer (e.g., Raspberry Pi) could do the image classification.
- **Sensors:** A soil moisture sensor (capacitive type) probes the soil moisture, connected to an analog pin of the Arduino. ADHT11 or DHT22 sensor provides ambient temperature and humidity readings. These sensors enable the robot to sense its environment continuously. The continuous acquisition of environmental data enables the Agribot to adapt its operation according to changing field conditions, thereby improving the efficiency of irrigation and crop management.
- **Actuators and Power:** Two DC geared motors (with rubber wheels) provide locomotion. An L293D dual H-bridge IC drives these motors, allowing forward/reverse control. A small DC motor drives the digging attachment, and a servo motor could control an opening mechanism for the seed hopper. The coordinated operation of the digging mechanism and seed dispensing unit enables accurate and consistent seed placement during planting operations. The water pump and pesticide pump are 5–12V diaphragm pumps; each is switched on/off by a relay module under Arduino control. All electronics are powered by a 12V battery; onboard regulators produce 5V for logic.
- **Wireless Module:** An ESP8266 Wi-Fi module (or Bluetooth/Zigbee module) links the Arduino to an Android phone. The wireless communication interface enables real-time monitoring and remote supervision of the Agribot without requiring physical access to the robot. The phone runs a custom app (or a generic serial terminal) that displays sensor readings and camera images, and can send commands (e.g. start/stop spraying).
- **Mobile App:** The smartphone interface shows real-time data (e.g., moisture level, camera view, battery status) and has buttons to start irrigation or spraying manually if needed. The application provides a user-friendly interface that simplifies interaction with the robotic platform and improves operational convenience. It communicates with the Arduino via Wi-Fi and TCP or via Bluetooth SPP.

The system software on the Arduino follows the flow described above. The embedded software is developed using the Arduino IDE and structured into modular routines for sensor acquisition, actuator control, communication, and decision-making. Libraries for sensor reading and communication were used. The CNN model for disease detection was pre-trained offline on labeled images of healthy and diseased crops; the resulting classifier weights are loaded onto the Agribot's processor. The main loop periodically takes a photo, runs classification, and activates the spray mechanism (a peristaltic pump) if a disease is found. Concurrently, it monitors soil moisture: if it reads below the threshold value, it turns on the water pump to irrigate the plant. This parallel execution of disease detection and irrigation control enables the Agribot to perform multiple agricultural operations simultaneously, thereby improving overall farming efficiency.

Physically, the robot's chassis supports the seed hopper on top and the water/pesticide tanks in a waterproof container. The structural arrangement ensures balanced weight distribution, providing stability during movement and agricultural operations. The digging tool and leveler are mounted beneath on a frame that can be raised/lowered by small linear actuators. The movable digging mechanism enables precise control of planting depth and facilitates accurate seed placement under varying soil conditions. The robotic platform is compact (about 50×30cm) form and maneuverability in small fields.

6. Results

The implemented Agribot prototype was tested in a controlled environment to verify functionality of each module. The experimental evaluation was carried out to assess the performance of the sensing, navigation, communication, and automation modules under representative operating conditions. Each subsystem was tested independently before evaluating the integrated operation of the complete Agribot platform. During trials, the robot successfully performed the following tasks:

- **Autonomous navigation:** The Agribot followed a straight path along rows of simulated crop plants. The navigation system maintained stable movement while ensuring that the robot reached each predefined inspection point with minimal positional deviation. Wheel encoders and the pre-programmed route enabled it to stop at each plant for processing.
- **Disease detection and spraying:** The vision system correctly classified sample plant leaves. The trained convolutional neural network successfully distinguished between healthy and diseased plant samples under the experimental conditions. In tests using printed images of healthy and diseased leaves, the CNN model identified disease cases with high accuracy. Whenever a diseased plant was detected, the robot activated the spray pump for 1–2 seconds, applying pesticide. No spraying occurred for healthy plant images. This demonstrated that the targeted spraying function operated as intended.
- **Soil moisture control:** The moisture sensor was calibrated so that it read high values in wet soil and low values in dry soil. Calibration ensured stable and reliable sensor measurements before field operation commenced. In a dry-soil test, the Agribot detected the low moisture level and automatically turned on the water pump until the soil sensor reported sufficient moisture. This validated the automated irrigation feature.

Seeding and leveling (functional only): The digging motor successfully created furrows of fixed depth, and the hopper released one seed per hole. The seed dispensing mechanism maintained uniform seed spacing and consistent planting depth throughout repeated experimental trials. The leveler arm then smoothed the soil. Although this feature was included, most of our tests focused on the monitoring functions (disease detection and irrigation). Nonetheless, the planting mechanism operated consistently with the design parameters.

Communication: The smartphone app maintained a live connection to the Agribot. The wireless communication interface enabled uninterrupted transmission of sensor data and operational status information during the experimental evaluation. Sensor readings and camera images could be viewed in real time, and manual commands (e.g., forcing a spray or irrigation) could be issued remotely. This confirmed that the wireless control link was reliable at short range.

Throughout the trials, the power supply and battery performed as expected. The electrical system maintained stable voltage levels throughout continuous operation without affecting the performance of the sensing, communication, or control modules. The Arduino and sensors operated on the 12V battery supply without resets or failures. The robot's motors and pumps drew no more current than anticipated, so a single battery provided continuous operation for several hours. Fig. 2 shows the prototype of the proposed Agribot developed for precision agriculture applications.

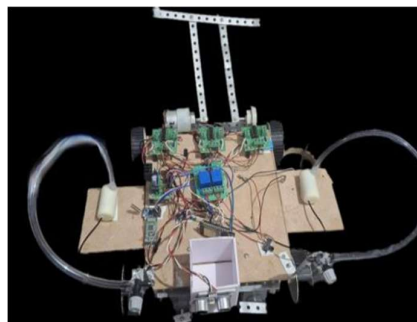


Fig.2. System Integration

7. Discussion

The experimental results indicate that the designed Agribot meets its key objectives. The successful integration of sensing, intelligent processing, and automated actuation demonstrates the practicality of the proposed system for precision agriculture applications. The prototype operated reliably during the experimental evaluation, confirming the effectiveness of the overall system architecture. The integration of AI-based vision with precise actuation allows for intelligent, selective treatment of plants. By spraying only when disease is detected, the system significantly reduces unnecessary pesticide use compared to blanket spraying. This targeted approach is both cost-effective and environmentally friendly. The automatic irrigation feature ensures that plants are watered only when needed, improving water use efficiency and avoiding plant stress.

The modular design proved effective: separating the sensing (camera, moisture sensor) from actuation (pumps, motors) allowed each subsystem to be optimized independently. The modular architecture also simplifies maintenance, troubleshooting, and future hardware upgrades without requiring major modifications to the complete system. For instance, the machine vision can be improved or updated without altering the watering hardware. Similarly, the smartphone interface can be extended to display additional data (e.g., battery level, GPS coordinates) thanks to the flexible wireless link.

However, some limitations were observed. Like most AI-based systems, the performance of the proposed Agribot is influenced by environmental conditions such as lighting variations, shadows, and occlusion of plant leaves during image acquisition. The accuracy of disease detection depends on the quality and representativeness of the training data. In our tests, the classifier worked well for the diseases it was trained on, but novel plant disorders would require retraining the model. The robot's navigation was kept simple; complex terrain or obstacle avoidance were not addressed in our prototype. In practice, uneven ground or field obstacles (rocks, debris) could impede movement. Battery life is also a constraint: while adequate for small fields, larger plots may require higher-capacity power or solar recharging to operate for extended periods.

Mechanical reliability is another consideration. The long-term durability of moving components is important because agricultural environments often expose mechanical systems to dust, moisture, vibration, and uneven terrain. The digging and dispensing mechanisms must be precisely timed; misalignment could cause seeds to be dropped inaccurately. During testing, occasional seed jams in the hopper were observed, suggesting a need for refinement of the feeder design. Moreover, the pump flow rates and spray nozzles must be calibrated to apply the correct pesticide dose. These factors will require optimization in future iterations.

Despite these issues, the Agribot demonstrated a viable multipurpose platform. The integration of intelligent sensing, automated irrigation, precision pesticide application, and wireless monitoring into a single platform distinguishes the proposed system from conventional agricultural equipment that typically performs only individual tasks. Its advantages include reduced manual labor, consistent planting/spraying actions, and data logging for decision support. By contrast, disadvantages include its initial complexity and cost (sensors, camera, pumps are more expensive than basic farm tools) and the dependence on electronics that require maintenance. Overall, the benefits to yield and sustainability are expected to outweigh these drawbacks in medium-term use.

8. Conclusion

This project developed an AI-based agricultural robot capable of detecting plant disease and applying precise pesticide spraying, while also handling irrigation and navigation. The proposed Agribot successfully integrates artificial intelligence, embedded control, environmental sensing, and wireless communication into a unified platform for precision agriculture. The prototype used computer vision (via a trained neural network) to identify unhealthy plants in real time, and actuated as a sprayer to treat only those plants. Soil moisture sensing enabled on-demand irrigation, and a seed-dispensing mechanism allowed for automated sowing. The embedded system, centered on an Arduino microcontroller, demonstrated coordinated control of all subsystems, with optional smartphone integration for monitoring and control.

In field tests, the Agribot successfully executed its intended functions: it navigated a test plot, monitored environmental conditions, detected simulated diseases, and activated the appropriate pumps for spraying and watering. The experimental evaluation verified the reliable operation of the sensing, processing, communication, and actuation modules under controlled testing conditions. These results confirm the feasibility of a low-cost, multipurpose agribot that can reduce labor, lower chemical usage, and improve crop management.

Future work can extend the Agribot's capabilities by incorporating predictive analytics and enhanced connectivity. For instance, the system could use historical weather and disease data to forecast outbreaks and preemptively adjust treatments. Cloud-based coordination of multiple robots could enable coverage of larger fields, while adaptive learning algorithms would allow the AI to recognize new crop varieties or conditions. Future versions may also incorporate deep learning models with higher classification accuracy, GPS-assisted autonomous navigation, obstacle avoidance systems, and Internet of Things (IoT)-based remote farm management for large-scale agricultural deployment. Renewable energy sources (such as solar panels) could be added to prolong operation in remote areas. Voice or mobile-app interfaces could improve usability for farmers. Such enhancements would further increase the agribot's utility in precision farming, moving toward fully automated and sustainable agriculture.

Compliance with Ethical Standards

Conflicts of interest: Authors declared that they have no conflict of interest.

Human participants: The conducted research follows the ethical standards and the authors ensured that they have not conducted any studies with human participants or animals.

References

- [1] M. Sunitha Seeding Robot, Intl. Conf. on Information, Engineering, Management and Security (ICIEMS), 2014.
- [2] M. Priyadarshini and L. Sheela, Command Based Self-Guided Digging and Seed Sowing Rover, International Conf. on Engineering Trends and Science & Humanities (ICETSH), 2015.
- [3] A. Singh, A. Gupta, A. Bhosale, and S. Poddar, Agribot: An Agriculture Robot, International Journal of Advanced Research in Computer and Communication Engineering, vol.4, no.1, Jan.2015.
- [4] N. Firthous Begum and P. Vignesh, Design and Implementation of Pick and Place Robot with Wireless Charging Application, International Journal of Science and Research (IJSR), 2013.
- [5] N. Buniyamin, W.A.J. Wan Ngah, N. Sariff, and Z. Mohamad, A Simple Local Path Planning Algorithm for Autonomous Mobile Robots, International Journal of Systems Applications, Engineering & Development, vol. 5, no. 2, 2011.
- [6] J. Bac, E. J. van Henten, J. Hemming, and Y. Edan, "Harvesting Robots for High-Value Crops: State-of-the-Art Review and Challenges Ahead," Journal of Field Robotics, vol. 31, no. 6, pp. 888–911, 2014.
- [7] S. Bechar and C. Vigneault, "Agricultural Robots for Field Operations: Concepts and Components," Biosystems Engineering, vol. 149, pp. 94–111, 2016.
- [8] S. Sladojevic, M. Arsenovic, A. Anderla, D. Culibrk, and D. Stefanovic, "Deep Neural Networks Based Recognition of Plant Diseases by Leaf Image Classification," Computational Intelligence and Neuroscience, vol. 2016, Article ID 3289801, 2016.
- [9] K. P. Ferentinos, "Deep Learning Models for Plant Disease Detection and Diagnosis," Computers and Electronics in Agriculture, vol. 145, pp. 311–318, 2018.
- [10] A. Kamilaris and F. X. Prenafeta-Boldú, "Deep Learning in Agriculture: A Survey," Computers and Electronics in Agriculture, vol. 147, pp. 70–90, 2018.
- [11] S. Wolfert, L. Ge, C. Verdouw, and M. J. Bogaardt, "Big Data in Smart Farming—A Review," Agricultural Systems, vol. 153, pp. 69–80, 2017.
- [12] J. Hemming, T. Rath, D. Barth, and H. Henten, "Computer Vision for Agriculture," in Springer Handbook of Agricultural Engineering, Springer, 2019.
- [13] S. Sankaran, A. Mishra, R. Ehsani, and C. Davis, "A Review of Advanced Techniques for Detecting Plant Diseases," Computers and Electronics in Agriculture, vol. 72, no. 1, pp. 1–13, 2010.
- [14] M. R. Bendre, V. N. Thool, and R. C. Thool, "Agricultural Field Monitoring and Automation Using IoT," Procedia Computer Science, vol. 78, pp. 270–275, 2016.
- [15] A. Khanna and S. Kaur, "Evolution of Internet of Things (IoT) and Its Significant Impact in the Field of Precision Agriculture," Computers and Electronics in Agriculture, vol. 157, pp. 218–231, 2019.