ISSN NO. 2320-5407

Journal Homepage: - www.journalijar.com

INTERNATIONAL JOURNAL OF ADVANCED RESEARCH (IJAR)

Article DOI: 10.21474/IJAR01/21402
DOI URL: http://dx.doi.org/10.21474/IJAR01/21402

RESEARCH ARTICLE

IOT BASED AUTONOMOUS ROBOT FOR AGRICULTURAL MONITORING AND HAZARD DETECTION

Saloni S Biradar, Shrinivas P Mahajan and Sandeep S. Anasane

Manuscript Info

Manuscript History
Received: 14 May 2025
Final Accepted: 17 June 2025
Published: July 2025

Key words:-
Color Sensor, LCD, Ultrasonic Sensor, Robot, Agriculture, GPS.

Abstract

The rising need for smart agricultural practices and automation has led to the emergence of intelligent systems that aim to boost productivity while ensuring environmental and operational safety. In response to this demand, the project titled "IoT-Based Autonomous Robot for Agricultural Monitoring and Hazard Detection" introduces an advanced robotic platform capable of autonomous navigation and real-time environmental assessment in agricultural fields. The central component This system is centered around the Arduino Mega 2560 board, serving as the primary controller for multiple integrated sensors. Among these are the DHT11, used to monitor both temperature and humidity levels, and the MQ135, which is designed for air quality detecting air pollutants, a color sensor for early plant disease identification, and an ultrasonic sensor for detecting obstacles. To support field navigation and communication, the system employs a GPS module for live tracking and a GSM module that transmits alerts during hazardous conditions. The robot moves using DC motors attached to a four-wheel chassis, and a motor driver coordinates its movement. This autonomous robot is also equipped with a pesticide spraying mechanism powered by a water pump, which is managed through a relay system, allowing it to operate independently in pest control. For enhanced monitoring, sensor data is transmitted to Through the NodeMCU module, the system connects to the Adafruit cloud platform, allowing for internet-based remote monitoring and control. Additionally, an IP camera streams live video, facilitating real-time observation of the agricultural field. The entire system is powered by a 12V battery, and an LCD screen offers immediate feedback on sensor readings and operational status. This integrated IoT-based approach not only streamlines crop management but also introduces a scalable, affordable solution to modern agriculture. By combining automation, data-driven insights, and real-time communication, the robot contributes significantly to the evolution of precision farming.

Introduction:-

Driverless tractors have become a pivotal innovation In contemporary farming, these self-operating machines utilize

Corresponding Author:- Saloni S Biradar

automation and precision to help farmers increase productivity. By integrating GPS, sensors, and AI technologies, these robots are It is designed to perform various farming-related operations, such as but not limited to agricultural activities plowing.sowing, These machines are designed to carry out tasks such as planting, harvesting, and plowing with little to no human involvement. By lessening the dependence on human labor.

In precision agriculture, drones have emerged as vital instruments, allowing farmers to closely monitor their crops, evaluate soil health, and manage fields with remarkable precision. Equipped with high-tech imaging systems and sensory devices, these autonomous drones are designed to operate without human intervention gather real-time data, enabling the detection of problems like pest invasions, nutrient shortages, and irrigation requirements. By enabling targeted interventions and efficient resource allocation, drones contribute to higher crop productivity and reduced environmental impact. Their role in data collection and analysis also supports timely decision-making, making farming practices more sustainable and cost-effective.

Blockchain technology is increasingly being adopted in agriculture to streamline Blockchain enhances supply chain processes by ensuring clear visibility, secure tracking, and verifiable authenticity. Through decentralized record-keeping of each transaction, it minimizes the risk of tampering, confirms the legitimacy of products, and streamlines the delivery timeline from producers to end-users. This innovation also grants stakeholders real-time access to critical supply chain data. By providing up-to-the-minute information on product origins, handling processes, and delivery schedules, this system enhances transparency and fosters better coordination and trust throughout the supply chain.

Smart contracts offer promising opportunities for automating transactions and agreements within the agricultural sector by using blockchain technology. These digital contracts can help reduce reliance on intermediaries, ensure faster payments, and improve trust among stakeholders through transparent and tamper-proof records. However, their adoption also faces challenges such as limited technological infrastructure in rural areas, legal uncertainties, and the need for farmers to become familiar with complex digital tools. Addressing these barriers is essential for Unlocking the complete capabilities of smart contracts has the potential to revolutionize agricultural operations, leading to more streamlined and efficient management of the supply chain.

Vertical farming offers an innovative and sustainable method for growing crops in urban environments by utilizing vertically stacked layers, often integrated with controlled-environment agriculture technology. This approach significantly reduces By utilizing methods like hydroponics, aeroponics, and LED-based illumination, this approach significantly reduces dependency on cultivable land and conserves water resources. It also facilitates continuous, year-round crop production in proximity to metropolitan areas it enhances productivity and reduces transportation emissions. Vertical farming contributes to food security and environmental conservation, making it a viable solution for addressing the challenges of urbanization and resource scarcity.

Materials And Methods:-

RELATED WORKS:

The integration of IoT in precision agriculture is bringing a revolutionary change to farming practices, Facilitating immediate observation and intelligent decision-making, this system relies on a web of interconnected devices that continuously share and process data in real time This innovation offers numerous advantages, such as better resource management, enhanced crop production, and the early identification of problems like pest outbreaks or soil health issues. However, its adoption comes with challenges, including the high upfront investment, concerns over data security, connectivity limitations in rural regions, and the need for farmers to acquire specialized technical skills. Despite these obstacles, the growing use of IoT in agriculture is steadily progressing.

The incorporation of IoT and robotics into agricultural practices has revolutionized farming by enhancing automation, accuracy, and overall operational efficiency. These advanced technologies enable continuous monitoring of variables like soil By analyzing factors such as soil quality, plant vitality, and surrounding environmental conditions, farmers are equipped to make informed decisions based on accurate, real-time data insights decisions that minimize resource wastage. Robotics further aids in performing labor-intensive tasks such as planting, harvesting, and spraying, thereby boosting productivity. However, the widespread adoption of these innovations faces several challenges, such as high upfront costs, technical difficulties, data management concerns,

and limited availability in rural regions. Despite these hurdles, the potential for these technologies to reshape agriculture into a more efficient, sustainable, and data-centric industry continues to offer significant promise.
The application of IoT technology in agriculture The integration of IoT technology has revolutionized how sensors are applied in agricultural practices to oversee and regulate various farming conditions. By connecting sensors to an intelligent IoT infrastructure, farmers gain continuous access to live data regarding soil moisture levels, ambient temperature, humidity, and the overall condition of crops, thus supporting precise and well-informed agricultural decisions. This data aids in fine-tuning irrigation schedules, identifying potential diseases early, and optimizing the use of resources. Additionally, combining sensor data with automated systems reduces This technology-driven method significantly reduces dependency on human labor while enhancing the effectiveness of farm operations. Additionally, it encourages environmentally sustainable agriculture by optimizing the consumption of essential resources such as fertilizers and water.

Robotics is revolutionizing modern agriculture by enhancing operational efficiency, improving accuracy, and facilitating higher automation levels. These advanced technologies are employed in various tasks such as planting, harvesting, weeding, and crop monitoring, significantly decreasing reliance on human labor. Leveraging sensors and machine learning algorithms, agricultural robots are capable of making instant decisions and adjusting to changing field conditions. This precision not only increases productivity but also reduces waste and the excessive use of resources like water and fertilizers. Consequently, robotics is assisting farmers in addressing the rising demand for food while supporting sustainable and intelligent farming techniques.

The adoption of IoT in agriculture offers significant potential for emerging economies by boosting productivity, improving resource management, and enabling data-driven decisions. By incorporating real-time data, smart devices, and various sensors into a unified system, seamless monitoring and automation of processes becomes achievable., assess crop health, and manage irrigation systems more effectively, ultimately leading to higher yields and less waste. Overcoming these obstacles will be essential to fully harness the benefits of IoT, driving sustainable agricultural development and enhancing livelihoods in emerging economies.

The integration of swarm robotics and artificial intelligence (AI) is revolutionizing agriculture by providing innovative solutions that enhance efficiency and productivity. Swarm robotics involves the use of multiple robots working together to carry out tasks like planting, harvesting, and crop monitoring. When paired with AI, these systems can analyze data in real time, streamline agricultural operations, and adjust to dynamic environmental factors. Growing investments in autonomous technologies are driving advancements that reduce labor costs, improve precision, and lower the environmental footprint of farming. Despite these promising developments, challenges such as significant initial expenses, technical complexity, and the need for a robust infrastructure remain, and addressing these hurdles is crucial for unlocking the full potential of swarm robotics and AI in agriculture.
Merging robotics with Internet of Things (IoT) technologies in agriculture presents transformative opportunities, especially for small-scale farmers.

Through constant monitoring of variables like soil quality, climatic changes, and crop status, these innovations enable smarter crop management. Automated systems can efficiently handle processes like seeding, irrigation, and harvesting, leading to reduced manpower requirements and increased farming efficiency Meanwhile, IoT devices like sensors and connected networks allow farmers to remotely monitor their fields, facilitating data-driven decision-making. This combination not only improves farming accuracy but also helps optimize the use of resources, minimize waste, and increase crop yields. However, the widespread adoption of these technologies faces challenges, such as high setup costs, limited access to technological infrastructure, and the need for specialized technical skills.
Smart farm modeling employs cutting-edge methods to enhance agricultural practices by utilizing data to inform decision-making. Through the integration of sensors, IoT devices, and sophisticated computational models, smart farms can track key variables such as soil health, crop status, and environmental factors in real time.

These models enable farmers to forecast results, optimize resource usage, and automate tasks like irrigation and fertilization. However, successfully implementing smart farm models requires addressing challenges such as the adoption of new technologies, effective data management, and the development of necessary infrastructure.
This technology utilizes a wireless ZigBee device with multi-power capabilities to improve remote sensing in precision viticulture. ZigBee, a low-energy wireless communication protocol, facilitates continuous monitoring of key environmental variables such as temperature, humidity, and soil conditions, all of which are vital for effective vineyard management. The device's multi-power design allows it to function autonomously for long periods,

drawing energy from various sources like solar power, making it suitable for remote vineyard settings. These devices provide real-time data, aiding viticulturists in making more accurate decisions regarding irrigation, pest management, and vineyard health, ultimately enhancing farming efficiency and sustainability in viticulture.

The Internet of Things (IoT) is a groundbreaking technology with the potential to transform various industries by facilitating smooth communication and data sharing between devices and systems. By connecting sensors, intelligent devices, and data analytics, IoT enables real-time monitoring and automation across sectors such as healthcare, agriculture, transportation, and smart cities. This technology enhances operational efficiency, reduces expenses, and supports better decision-making, creating vast opportunities for future technological growth. However, as IoT adoption grows, issues related to data security, privacy, and system compatibility must be resolved to fully capitalize on its advantages and foster new avenues for innovation.

The use The application of big data analytics is reshaping modern agriculture by harnessing vast datasets gathered from various origins, such as sensor networks, meteorological inputs, and satellite imagery. This wealth of information equips farmers with deeper insights, enabling more precise decisions regarding irrigation strategies, pest mitigation, crop planning, and efficient resource distribution—ultimately enhancing productivity and maximizing crop output.Advanced analytical methods allow for predictive models, trend analysis, and real-time decision-making, optimizing farming practices. However, challenges such as ensuring data quality, addressing privacy issues, and the need for specialized expertise in interpreting this data continue to pose barriers to broader adoption within the agricultural industry.

Incorporating Internet of Things (IoT) technology into irrigation systems is revolutionizing modern agriculture by enabling automated, data-driven methods that enhance water efficiency and reduce wastage. By incorporating a range of IoT sensors, including By employing tools such as moisture level sensors, climate tracking units, and water flow gauges, farmers are empowered to observe environmental parameters in real-time and determine optimal irrigation schedules. This approach significantly reduces unnecessary water use, guarantees appropriate hydration for crops, and improves overall water management. Furthermore, IoT-enabled platforms allow remote supervision and control, giving farmers the flexibility to adjust irrigation processes dynamically based on live data. As a result, this not only improves agricultural productivity but also promotes sustainable use of water resources.

Temperature monitoring systems for forest fire detection, powered by IoT and enhanced with machine learning algorithms, provide a highly effective method for early detection and prevention of wildfires. The system utilizes a network of temperature sensors placed throughout forested regions to continuously gather environmental data. Machine learning models process the gathered information to detect irregular trends or anomalies that could indicate an early-stage fire risk. By leveraging both historical and real-time information, these models can predict fire risks, enabling faster responses and more precise warnings. This approach not only improves forest safety but also aids in better resource management and reduces fire-related damage, offering a proactive means of safeguarding forests.
The use of robotics in precision agriculture is transforming farming practices by providing automated solutions that enhance operational efficiency, precision, and sustainability.

Robots Equipped with state-of-the-art sensors, GPS systems, and intelligent machine learning algorithms, modern agricultural robots handle tasks like sowing, weeding, watering, and harvesting with precision. These sophisticated technologies enhance crop supervision and enable efficient resource utilization—including water, fertilizers, and pesticides—leading to reduced operational costs and minimized environmental impact. The adoption of robotics in farming not only elevates productivity and crop standards but also advances sustainable agricultural practices agricultural practices is supported, benefiting both large-scale and smallholder farmers.

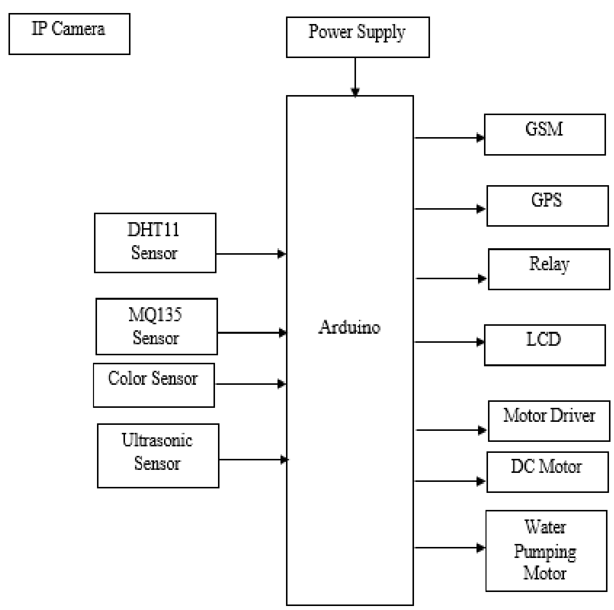
Unmanned Aerial Vehicles (UAVs) are becoming a crucial tool in modern agriculture, offering advanced capabilities for aerial surveillance and data gathering to improve farming techniques. These drones Drones integrated with various advanced tools—including thermal sensors, multispectral imaging systems, and GPS navigation—facilitate precise monitoring of factors like soil condition, plant vitality, and water distribution. These aerial systems deliver up-to-the-minute insights, empowering agriculturalists to optimize practices such as watering schedules, nutrient application, pest control, and general crop maintenance, thereby enhancing productivity while reducing operational costs. With the ability to monitor expansive agricultural areas remotely, UAV technology boosts the scalability and sustainability of farming operations, fostering more efficient and data-driven approaches to agriculture.

Proposed Method:-

This project outlines a method for developing and deploying an autonomous robotic system that integrates various sensors to monitor environmental factors and identify potential threats in agricultural fields. The system's primary control unit is the Arduino Mega 2560, which orchestrates multiple sensors to gather critical environmental data. Among these are the DHT11 sensor for detecting ambient temperature and humidity, the MQ135 module for measuring air pollutants, and a color sensor designed to identify early signs of plant disease and an ultrasonic sensor for obstacle avoidance. Together, these sensors offer a detailed environmental overview, enabling the robot to navigate the agricultural landscape independently. The robot's movement is driven by DC motors mounted on a four-wheel chassis, with a motor driver ensuring precise control. For real-time tracking, a GPS module provides location data, while a GSM module sends notifications if hazardous or abnormal conditions are detected, enabling prompt action when needed.

The robot is further designed with an automated pesticide spraying system, powered by a water pump that is regulated by a relay for effective pest control. Sensor data is sent to the Adafruit cloud platform via a NodeMCU, enabling remote access and management through an internet connection. Additionally, an IP camera is incorporated for live video streaming, offering real-time monitoring capabilities. A 12V battery ensures uninterrupted power supply, while an LCD screen continuously shows sensor readings and system status for quick reference. This approach not only provides a fully automated solution for agricultural monitoring but also leverages IoT technology for efficient data gathering, remote control, and instant hazard detection, making it a cost-effective and scalable advancement in contemporary farming techniques.

Block Diagram:-



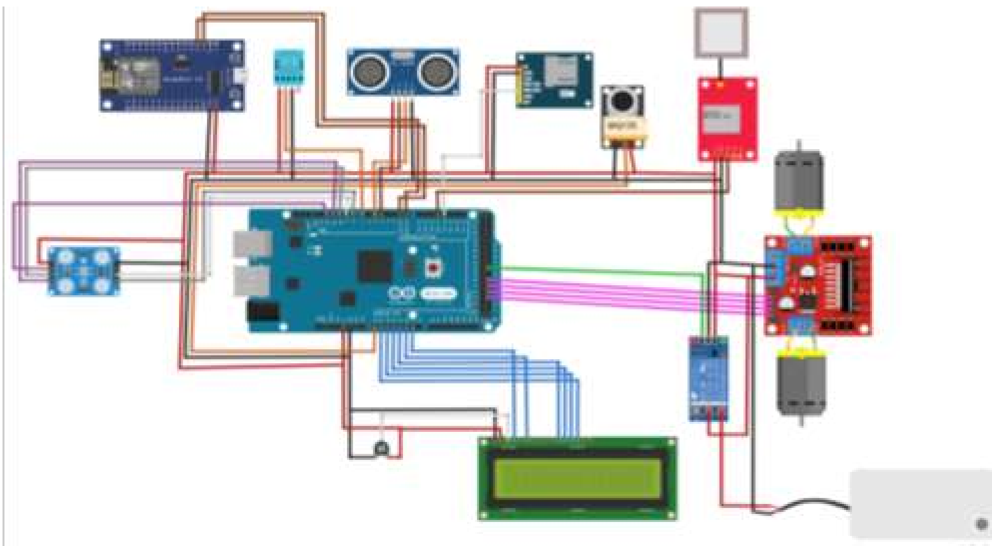
Methodology:-

WORKING

This project operates through the autonomous movement of the robot across agricultural fields, utilizing an Arduino Mega 2560 microcontroller to control various sensors. The system includes a DHT11 sensor to measure temperature and humidity, an MQ135 sensor for detecting air pollution, and a color sensor to detect early signs of plant diseases. An ultrasonic sensor enables the robot to avoid obstacles, ensuring it moves efficiently through the field. The GPS module continuously tracks the robot's location, while the GSM module sends notifications in case of detected hazards, such as extreme weather conditions or unusual sensor data. The robot's mobility is powered by DC motors on a four-wheel chassis, with the motor driver offering accurate control over speed and direction.

In addition to navigating the field, the robot is equipped with an autonomous pest control system thatmanages pesticide application. The water pump, controlled by a relay, allows the robot to dispense pesticides automatically when needed, making it a key asset for effective crop management. Sensor data is transmitted to the Adafruit cloud platform via the NodeMCU, enabling remote monitoring and control. To enhance the system's functionality, an IP camera streams live video, offering real-time visual updates from the field. A 12V battery powers the robot, ensuring it operates continuously, while the LCD screen displays real-time sensor data and system status, providing immediate feedback to the user. This integration of autonomous navigation, environmental monitoring, and pest control positions the robot as a highly efficient tool for modern precision agriculture.

Hardware Circuit Diagram
The figure below illustrates the complete circuit wiring of the IoT-based autonomousrobot for agriculture monitoring and hazard detection robot. It was designed using the Fritzing software to show actual component connections including:



Working Principle:-
The working principle of the IoT-Based Autonomous Robot for Agricultural Monitoring and Hazard Detection revolves around autonomous navigation and real-time data collection from the environment. The Arduino Mega 2560 microcontroller serves as the brain of the robot, managing various sensors that monitor key agricultural parameters.MQ135 sensor detects quality of air, alerting the system to any harmful pollutants. The color sensor is used to identify early signs of plant diseases by analyzing color variations in leaves, and the ultrasonic sensor detects obstacles to prevent the robot from colliding with objects in the field. The GPS module tracks the robot's location, enabling precise navigation, and the GSM module transmits alerts when any abnormal conditions are detected, such as extreme environmental factors or hazardous situations.

In addition to monitoring the environmental conditions, the robot integrates a pesticide spraying system, which works autonomously to control pests in the field. This system is controlled by a water pump and relay, ensuring that pesticides are sprayed when needed without requiring human intervention. The data is uploaded to Adafruit cloud platform through the NodeMCU, enabling real-time remote monitoring via the internet. To provide additional surveillance, an IP camera streams live video, allowing users to monitor the field from a distance. The entire system operates on a 12V battery, providing sufficient power for continuous operation, while the LCD screen provides real-time feedback on sensor readings and robot status. This integration of sensors, cloud connectivity, and automation forms the foundation of the robot's operation, making it a smart and efficient solution for modern agricultural practices.

Key Feature:-

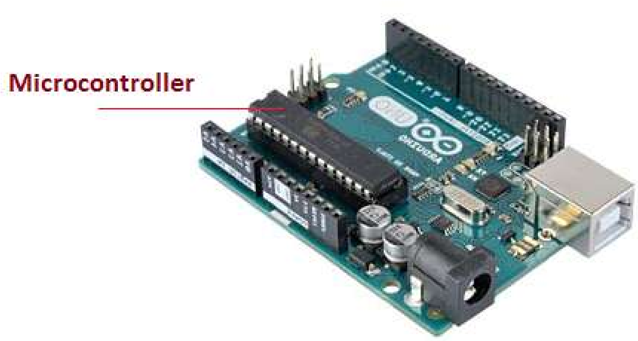
This IoT-Based Autonomous Robot for Agricultural Monitoring and Hazard Detection offers several key features that contribute to its effectiveness in smart farming. One of the standout features is its autonomous navigation capability, powered by a combination of sensors and a motorized chassis. The robot's navigation is facilitated by the GPS module, which provides precise location tracking, while the ultrasonic sensor ensures obstacle avoidance, allowing the robot to move freely within the agricultural fields. The integration of the color sensor enables early detection of plant diseases by analyzing color changes in leaves, offering timely intervention to prevent the spread of diseases.

Another notable feature is the robot's ability to autonomously manage pest control through the pesticide spraying mechanism. This system is activated by a water pump and controlled by a relay, allowing the robot to spray pesticides when necessary without requiring manual intervention. The IP camera adds an extra layer of surveillance by streaming live video, ensuring real-time field observation. Additionally, the robot is powered by a 12V battery, making it energy-efficient and capable of operating for extended periods. The LCD screen provides immediate feedback on the system's operational status, allowing the user to easily track performance and sensor readings. These key features collectively make the robot a comprehensive solution for modern, efficient, and autonomous agricultural management.

Component Requirements:-

The hardware components used in this project play a vital role in ensuring the autonomous robot functions effectively within agricultural fields. Central to the system is the Arduino Mega 2560 microcontroller, acting as the main control unit that coordinates and manages different sensors and modules. The DHT11 sensor plays a key role in tracking temperature and humidity, essential for evaluating the environmental factors within the farm. To detect air quality and harmful pollutants, the MQ135 gas sensor is incorporated, providing real-time data on air pollution levels. Additionally, the robot is equipped with a color sensor, which helps identify early signs of plant diseases by analyzing the color variations in plant leaves, enabling timely intervention. For movement, the system employs DC motors connected to a four-wheel chassis, which are controlled through a motor driver to facilitate navigation.
The robot's obstacle detection and avoidance are made possible by the ultrasonic sensor, which helps it detect objects in its path and navigate around them.

A GPS module provides precise location tracking, ensuring the robot can autonomously navigate the agricultural field and follow specific paths. To handle communication, the system uses a GSM module to send alerts in case of hazardous conditions, and a NodeMCU module facilitates data transmission to the Adafruit cloud platform for remote monitoring. For pest control, the robot features a water pump controlled by a relay system that enables autonomous pesticide spraying. An LCD screen provides immediate status updates, allowing for quick monitoring of sensor readings and system conditions. These hardware components work in tandem to create an integrated, self-sufficient system that is capable of improving efficiency in agricultural management.

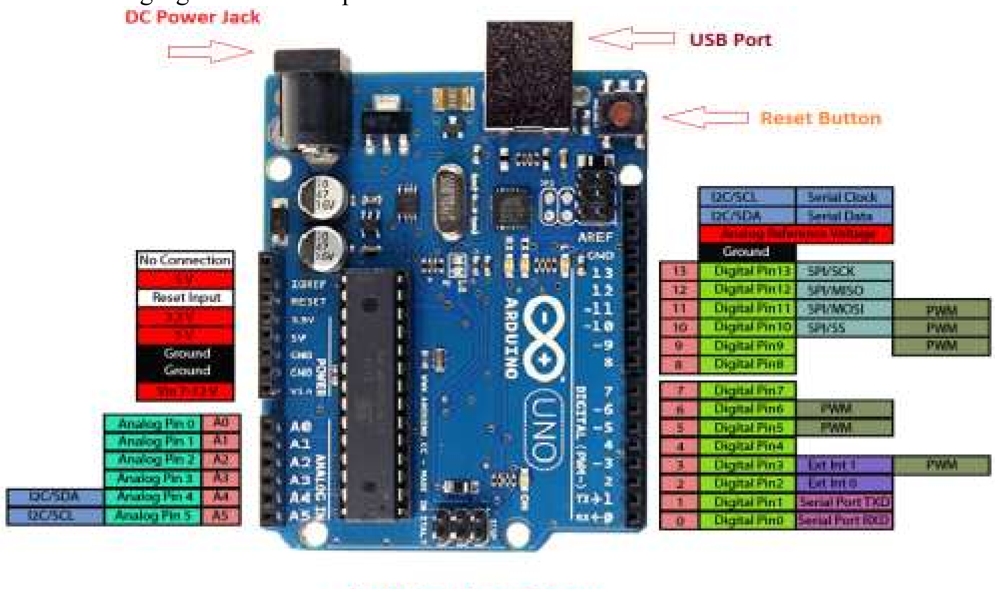


Arduino Board

Microcontroller

Arduino Pinout

- Arduino Uno is based on AVR microcontroller called Atmega328. This controller comes with 2KB SRAM, 32KB of flash memory, 1KB of EEPROM. Arduino Board comes with 14 digital pins and 6 analog pins. ON-chip ADC is used to sample these pins. A 16 MHz frequency crystal oscillator is equipped on the board. Following figure shows the pinout of the Arduino Uno Board



Pin Description:-

There are several I/O digital and analog pins placed on the board which operates at 5V. These pins come with standard operating ratings ranging between 20mA to 40mA. Internal pull-up resistors are used in the board that limits the current exceeding from the given operating conditions. However, too much increase in current makes these resisters useless and damages the device.

LED. Arduino Uno comes with built-in LED which is connected through pin 13. Providing HIGH value to the pin will turn it ON and LOW will turn it OFF.

Vin. It is the input voltage provided to the Arduino Board. It is different than 5 V supplied through a USB port. This pin is used to supply voltage. If a voltage is provided through power jack, it can be accessed through this pin.
5V. This board comes with the ability to provide voltage regulation. 5V pin is used to provide output regulated voltage. The board is powered up using three ways i.e. USB, Vin pin of the board or DC power jack.

USB supports voltage around 5V while Vin and Power Jack support a voltage ranges between 7V to 20V. It is recommended to operate the board on 5V. It is important to note that, if a voltage is supplied through 5V or 3.3V pins, they result in bypassing the voltage regulation that can damage the board if voltage surpasses from its limit.
GND. These are ground pins. More than one ground pins are provided on the board which can be used as per requirement.

Reset. This pin is incorporated on the board which resets the program running on the board. Instead of physical reset on the board, IDE comes with a feature of resetting the board through programming.
IOREF. This pin is very useful for providing voltage reference to the board. A shield is used to read the voltage across this pin which then select the proper power source.

PWM. PWM is provided by 3, 5, 6,9,10, 11pins. These pins are configured to provide 8-bit output PWM.
SPI. It is known as Serial Peripheral Interface. Four pins 10(SS), 11(MOSI), 12(MISO), 13(SCK) provide SPI communication with the help of SPI library.

AREF. It is called Analog Reference. This pin is used for providing a reference voltage to the analog inputs.

TWI. It is called Two-wire Interface. TWI communication is accessed through Wire Library. A4 and A5 pins are used for this purpose.

Serial Communication. Serial communication is carried out through two pins called Pin 0 (Rx) and Pin 1 (Tx).Rx pin is used to receive data while Tx pin is used to transmit data.
External Interrupts. Pin 2 and 3 are used for providing external interrupts. An interrupt is called by providing LOW or changing value

LCD:
LCD (Liquid Crystal Display) is the innovation utilized in scratch pad shows and other littler PCs. Like innovation for light-producing diode (LED) and gas-plasma, LCDs permit presentations to be a lot more slender than innovation for cathode beam tube (CRT). LCDs expend considerably less power than LED shows and gas shows since they work as opposed to emanating it on the guideline of blocking light.

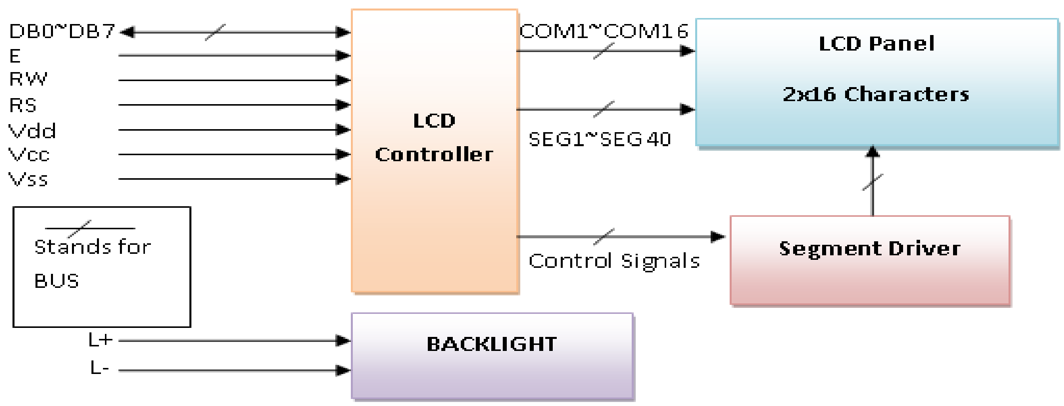
A LCD is either made with a uninvolved lattice or a showcase network for dynamic framework show. Likewise alluded to as a meager film transistor (TFT) show is the dynamic framework LCD. The uninvolved LCD lattice has a matrix of conductors at every crossing point of the network with pixels. Two conductors on the lattice send a current to control the light for any pixel. A functioning framework has a transistor situated at every pixel crossing point, requiring less current to control the luminance of a pixel.

The directions given to the LCD are put away by the order register. An order is a direction given to LCD to play out a predefined assignment, for example, introducing it, clearing its screen, setting the situation of the cursor, controlling presentation, and so forth. The information register will store the information that will be shown on the LCD. The information is the character's ASCII incentive to show on the LCD
Data/Signals/Execution of LCD
Now that was all about the signals and the hardware. Let us come to data, signals and execution.

Two types of signals are accepted by LCD, one is data and one is control. The LCD module recognizes these signals from the RS pin status. By pulling the R / W pin high, data can now also be read from the LCD display. Once the E pin has been pulsed, the LCD display reads and executes data at the falling edge of the pulse, the same for the transmission case.

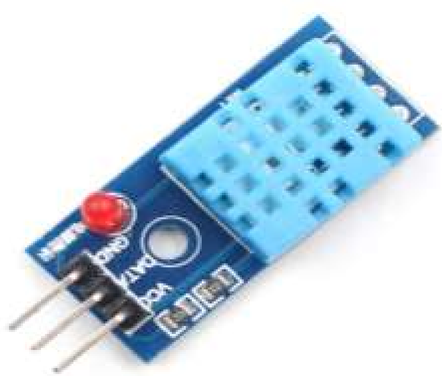
It takes 39-43µS for the LCD display to place a character or execute a command. It takes 1.53ms to 1.64ms except for clearing display and searching for cursor to the home position.
Any attempt to send data before this interval may result in failure in some devices to read data or execute the current data. Some devices compensate for the speed by storing some temporary registers with incoming data.
There are two RAMs for LCD displays, namely DDRAM and CGRAM. DDRAM registers the position in which the character would be displayed in the ASCII chart. Each DDRAM byte represents every single position on the display of the LCD.

The DDRAM information is read by the LCD controller and displayed on the LCD screen. CGRAM enables users to define their personalized characters. Address space is reserved for users for the first 16 ASCII characters.
Users can easily display their custom characters on the LCD screen after CGRAM has been set up to display characters.



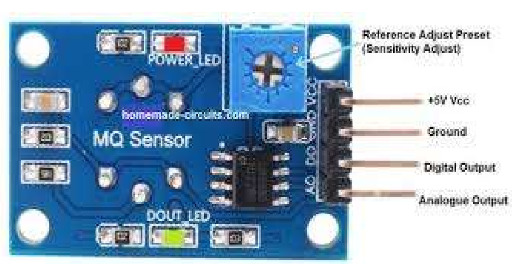
DHT11 SENSOR (TEMPERATURE/HUMIDITY):

A. The DHT11 is a basic, low-cost digital temperature and humidity sensor. It uses a capacitive humidity sensor and a thermistor to measure the surrounding air, and spits out a digital signal on the data pin (no analog input pins needed). It's fairly simple to use, but requires careful timing to grab data. The only real downside of this sensor is you can only get new data from it once every 2 seconds.



MQ135 Gas Sensor Module

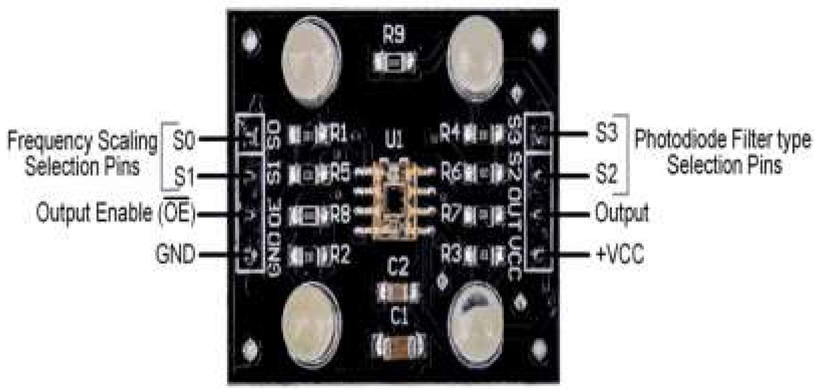
MQ-135 gas sensor can be implement to detect the smoke and other harmful gases. It has potential to detect different harmful gases, including NH3, NOx, alcohol, benzene, smoke and CO2. MQ135 gas sensor has high sensitivity to Ammonia, Sulfide and Benzene steam, also sensitive to smoke and other harmful gases.The analog level output provides an output voltage within the range of 0 to 4V based on the concentration of the hazardous gas in the environment; 0V for lowest concentration, 4V for maximum



The Module requires a 5V power supply and provides a digital Logic output (1 or 0) and an analog level output (0-4V). The digital logic output is LOW (0) when no gas is detected but goes HIGH (1) when hazardous gas concentration in the environment reaches the set threshold set via a potentiometer on the module.
After initial power ON, please wait at least 20 Seconds before reading outputs to ensure data validity. The Sensitive material used in MQ135 gas sensor is SnO_2. The conductivity of this material is lower in clean air. The sensor conductivity increases with the increasing concentration of target pollution gas.

TCS3200 Color Sensor Module

- Color Sensor Module has 4 LEDs with TCS3200 Color Sensor IC.
- Module is designed in such way that 4 bright LEDs will light the object and reflections from that object will strike the TCS3200 Color Sensor IC to detect the colour of an object.



FLOWCHART

1. Start
2. Initialize sensors and peripherals
3. Display welcome message on LCD
4. Read sensor data: temperature, gas, color, GPS, and distance
5. Evaluate conditions:
   - If distance < 25 cm → Stop & send alert
   - If gas > threshold → Stop & send alert
   - If red, green, and blue > 40 → Disease detected → Stop & send alert
   - Else → Continue operation
6. **Receive manual control command:**
   - '1': Forward
   - '2': Backward
   - '3': Right
   - '4': Left
   - '0': Stop
   - '5': Pump OFF
   - '6': Pump ON
7. **Send GPS location via GSM when alert condition is met**
8. **Repeat loop**

SAMPLE CODE SNIPPET (NODEMCU + ADAFRUIT IO)

```
#include <ESP8266WiFi.h>
#include "AdafruitIO_WiFi.h"
#include "DHT.h"
#include <SoftwareSerial.h>
SoftwareSerialbt(4, 5);  // (Rx,Tx)  only  4
// WiFi& Adafruit IO credentials
#define IO_USERNAME "Salonibiradar"
```

```
#define IO_KEY "aio_XDDJ27jeJPPyLXZYv3YceXqQzDZT"
char ssid[] = "water";
char pass[] = "123456789";
// DHT11 configuration
#define DHTPIN D2  // GPIO4
#define DHTTYPE DHT11
DHT dht(DHTPIN, DHTTYPE);
// Gas sensor pin (analog A0)
#define GAS_SENSOR A0
// Adafruit IO setup
AdafruitIO_WiFi io(IO_USERNAME, IO_KEY, ssid, pass);
AdafruitIO_Feed *keypad = io.feed("keypad");
AdafruitIO_Feed *temperature = io.feed("temperature");
AdafruitIO_Feed *humidity = io.feed("humidity");
AdafruitIO_Feed *gas = io.feed("gas");
// Sensor values
float h;
float t;
int gasValue;

void setup() {
Serial.begin(9600);
bt.begin(9600);  // Define baud rate for software serial communication
  // Start DHT sensor
dht.begin();

  // Connect to Adafruit IO
io.connect();
  keypad->onMessage(handleMessage);

  // Wait for a connection
  while (io.status() < AIO_CONNECTED) {
    delay(500);
  }

  // Serial.println("Connected to Adafruit IO");
}
void loop() {
io.run();  // Process Adafruit IO events

  // Read sensors
  h = dht.readHumidity();
  t = dht.readTemperature();
gasValue = analogRead(GAS_SENSOR);

  // Send data to Adafruit IO
  temperature->save(t);
  humidity->save(h);
  gas->save(gasValue);
  // String str = "a" + String(t, 2) + "b" + String(h, 2) + "c" + String(gasValue) + "d";
  // bt.println(str);
  delay(10000);  // Wait 5 seconds before next update
}

// Handle keypad input from Adafruit IO
void handleMessage(AdafruitIO_Data *data) {
```

```
  String reading = data->toChar();
Serial.println(reading);
}
```

ALERTS

In this project, alert systems are integrated to ensure timely intervention and enhance operational safety. The GSM module is a crucial component in the alert system, as it enables the robot to send real-time notifications to the user or farm operator during hazardous conditions, such as abnormal temperature, humidity, or air quality levels. Additionally, the system can send alerts when potential obstacles are detected or when the robot encounters operational issues, such as a malfunction in the pesticide spraying mechanism. These alerts are designed to keep the operator informed about critical conditions, allowing them to take necessary actions remotely. By transmitting data to the Adafruit cloud platform through the NodeMCU, the system ensures that the operator can monitor the robot's performance and receive updates regardless of their location processes.

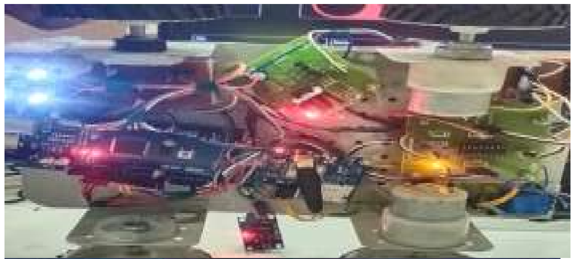
POWER REQUIREMENTS

The power requirements for this project are crucial to ensure that all components function efficiently and reliably during operation. The system is powered by a 12V DC battery, which is typically found in most vehicles. This battery supplies power to the Arduino microcontroller, sensors, and other components like the ultrasonic sensor, MEMS sensor, GPS module, GSM module, and the LCD display. The Arduino takes data from sensors and controlling the output devices, including the headlights and alert systems.

The sensors and modules used in this project have relatively low power consumption, making them suitable for continuous operation in a vehicle without significantly affecting the overall battery life. For example, the LDR sensor and ultrasonic sensor draw minimal current, while the GSM and GPS modules require slightly higher power, especially when sending messages or updating location data. To manage power consumption efficiently, such as turning off the GSM and GPS modules when they are not in use.

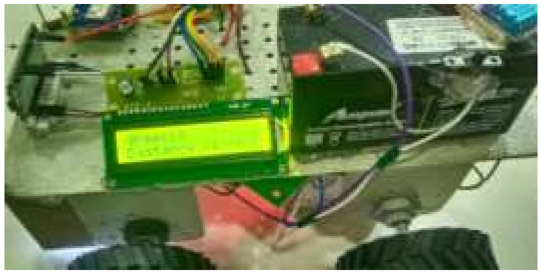
Result:-

The developed prototype successfully demonstrates autonomous navigation, environmental monitoring, live data transmission, and remote operation capabilities. Key sensor data (temperature, humidity, gas concentration, plant health status) are accurately captured and visualized in real-time on the cloud dashboard. The pesticide spraying mechanism responds effectively to control signals, and the video stream ensures field visibility. The system shows strong potential for scalability and adaptation to diverse agricultural environments




OFF
OFF
OFF
OFF
OFF
8
33.5
51


PUMP ON..!



Conclusion:-

To conclude, the IoT-Based Autonomous Robot for Agricultural Monitoring and Hazard Detection marks a significant leap forward in the field of smart farming. It offers a holistic solution to boost productivity, promote environmental sustainability, and enhance safety in agricultural operations. By integrating various sensors, real-time communication systems, and automation technologies, the robot facilitates autonomous navigation, pest control, and environmental monitoring in agricultural settings. This project highlights the promising role of IoT and robotics in precision agriculture, providing an efficient, scalable, and cost-effective approach to meet the growing demand for automation in farming. This innovation not only optimizes farming operations but also supports sustainable, data-driven agricultural practices, shaping the future of the industry.

References:-

1. J. Doe and A. Smith. Autonomous Driverless Tractors for Precision Farming. IEEE Trans. on Smart Agriculture. 2024; 5(17): 210–198.
2. R. Kumar, et al. IoT-Enabled Crop Disease Detection Using Multispectral Imaging and Machine Learning. IEEE Sensors Journal. 2024; 24(8): 645–631.
3. P. Roy and S. Banerjee. Cloud-Based Remote Monitoring of Agricultural Environments Using ESP8266 and MQTT. International Journal of IoT and Embedded Systems. 2023; 4(11): 88–74.
4. Y. Zhang, et al. Smart Pest Control Robot for Plantation Fields Using Ultrasonic and Color Sensors. Journal of Agricultural Robotics. 2022; 2(8): 134–118.
5. H. Liu and M. Chen. NodeMCU-Based Real-Time Environmental Monitoring in Greenhouses. Journal of Precision Agriculture Technologies. 2023; 3(15): 142–130.
6. V. Patel and J. Singh. Challenges and Advantages of Blockchain for Traceability in Smart Farming. IEEE Internet of Things Magazine. 2023; 6(4): 56–44.Gupta, et al. Smart Contracts and Blockchain in Agri-Supply Chain Management: A Systematic Review. Journal of Blockchain Applications in Agriculture. 2024; 1(5): 76–62.
7. K. Sharma and N. Mehta. Integration of Real-Time Video Streaming and Cloud Dashboards for Autonomous Agricultural Robots. IEEE Robotics and Automation Letters. 2022; 7(31): 98–84.
8. S. Karan. Contemporary Applications of Driverless Tractors in Smart Agriculture. Journal of Agricultural Innovation. 2023;3(18):59–45.
9. M. Johnson. Precision Agriculture and the Impact of Drones. Innovations in Agricultural Technology Journal. 2024; 4(24):126–112.
10. S. Patel. Enhancing Supply Chain Efficiency in Agriculture through Blockchain Technology. Journal of International Supply Chain Management. 2023; 2(13): 92–78.
11. N. Brown. Opportunities and Challenges of Smart Contracts in Agriculture. Agriculture and Blockchain. 2024; 7:27–15.
12. L. Anderson. A Sustainable Approach to Urban Agriculture: Vertical Farming. Journal of Urban Agricultural Solutions. 2024; 1(9):46–34.
13. T. Nguyen. Challenges and Benefits of IoT-Enabled Precision Agriculture. Review of Precision Agriculture. 2024; 3(16):115–101.
14. M.L. Alamaru, et al. Benefits and Challenges of IoT and Robotics in Agricultural Transformation. Journal of Smart Agricultural Systems. 2022; 34:9–1.
15. N.M. Kibria, et al. Data Collection, Sensors, and Management in Agriculture through IoT. IEEE Magazine on Internet of Things. 2021; 4(3):20–12.
16. D.T. Vasconcelos, et al. Efficiency, Precision, and Automation: The Impact of Robotics on Modern Agriculture. Agritech Review. 2020; 3(18):29–22.

17. J. Pierre, et al. Opportunities and Challenges of IoT-Based Agriculture in Emerging Economies. Journal of Rural Innovations IEEE. 2021; 2(2):38–31.
18. J.M. Rivera, et al. Future Perspectives and Current Trends of Swarm Robotics and AI in Agriculture. Agricultural AI Journal. 2022; 1:60–50.
19. S.W. Dhulipala, et al. The Impact of Robotics and IoT on Smart Agriculture for Smallholder Farmers. International Journal of Agricultural Technology. 2024; 2(35):230–215.
20. O'Hare, G.M., and O'Grady, M.J. Techniques and Methods for Modeling Intelligent Farms. In Agricultural Information Processing*.2018; 3(4):187–179.
21. R. Morais, et al. Wireless Multi-Powered ZigBee Device for Remote Sensing in Precision Viticulture Applications. Computers & Electronics in Agriculture. 2016; 2(68):286–274.
22. V. Venkataramanan, et al. Contactless Temperature Sensing and Smart Automatic COVID Door Opening System. e-Prime Journal of Advances in Electrical Engineering, Electronics, and Energy. 2024; 6:284–100.Kamilaris, A. Kartakoullis, Boldú, F.X. Prenafeta. Review on Agricultural Applications of Big Data Analytics. *Computers and Electronic Systems in Agriculture*.. 2018; 143:37–23.
23. N. Saeed, et al. Intelligent Irrigation Management for Smart Farming Using IoT. IEEE Access Journal. 2021; 8:55635–55622.
24. V. Venkataramanan, G. Kavitha, M.R. Joel, J. Lenin. Temperature Monitoring and Forest Fire Detection using IoT and Machine Learning Algorithms. 5th International Conference on Smart Systems and Innovative Technologies (ICSSIT). 2024; 5:1156–1150.
25. M.A. Hassan, U.R. Bhatti, A. Khan. Robotics in Precision Agriculture: Applications and Impact. Computers & Electronics in Agriculture. 2022; 182:106041.
26. J. Xiong, Q. Xie, G. Zhou. Applications and Technology of UAVs in Smart Agriculture: A Review.Computers & Electronics in Agriculture. 2023; 192:106610.
27. S. Kumar, P. Tiwari, M. Zymbler. A Review on IOT: A Revolutionary Approach for Future Technological Advancements. Journal of Big Data. 2020; 1(6):21–1.
28. Choudhury et al. Agriculture Field Automation and Digitization Using IoT and Machine Learning. Journal of Sensors. 2022; Article 9042382.
29. "Precision agriculture using IoT data analytics and machine learning." Journal of King Saud University – Computer & Information Sciences. 2022;34(8):5602–5618.
30. "The IoT and AI in Agriculture: The Time Is Now—A Systematic Review of Smart Sensing Technologies." Sensors (MDPI). 2025;25(12):3583.
31. Mudholkar et al. IoT in Agriculture: Precision Farming, Crop Monitoring, and Environmental Sustainability. Journal of Advanced Zoology. 202?;44(S2):1123.
32. Xavier et al. Smart Sensors and Smart Data for Precision Agriculture: A Review. Sensors (MDPI). 2024;24(8):2647.
33. Ahmad et al. IoT-Based Wireless Sensor Network for Precision Agriculture. IEEE iEECON Conference. 2019; pp.1–4.
34. Andrew et al. IoT Solutions for Precision Agriculture. MIPRO 2018; pp.0345–0349.
35. Grimblatt et al. Precision Agriculture for Small-to-Medium Farmers—an IoT Approach. ISCAS 2019; pp.1–5.
36. Marcu et al. IoT-Based System for Smart Agriculture. ECAI 2019; pp.1–4.
37. Dholu&Ghodinde. IoT for Precision Agriculture Applications. ICOEI 2018; pp.339–342.
38. Dolci. IoT Solutions for Precision Farming and Food Manufacturing. COMPSAC 2017; vol.2 pp.384–385.
39. Rekha et al. IoT-Based Precision Farming Framework for Groundnut. GHTC 2017; pp.1–5.
40. Saraf &Gawali. Smart Irrigation Monitoring & Control System (IoT). RTEICT 2017; pp.815–819.
41. Anitha et al. Smart Irrigation using IoT. IC-ETITE 2020; pp.1–7.
42. Laksiri et al. IoT-Based Smart Irrigation System in Sri Lanka. ICIIS 2019; pp.198–202.
43. Bhanu et al. Enhanced Irrigation Smart System via IoT. ICESC 2020; pp.760–765.
44. Mogili& Deepak. Review on Drone Systems in Precision Agriculture. Procedia Computer Science. 2018;133:502–509.
45. Maddikunta et al. Unmanned Aerial Vehicles in Smart Agriculture. IEEE Sensors Journal. 2021;–.
46. Wang et al. Machine Vision in Agri-Robot Navigation: A Review. Comput. Electron. Agric. 2022;198:107085.
47. Adamides& Edan. Human–Robot Collaboration in Agriculture Tasks: A Roadmap. Comput. Electron. Agric. 2023;204:107541.
48. Bai et al. Vision-Based Navigation for Agricultural Robots: A Review. Comput. Electron. Agric. 2023;205:107584.
49. Oliveira et al. Advances in Agricultural Robotics: State-of-the-Art and Challenges. Robotics. 2021;10(52).

50. Sara et al. Electric Autonomous Robot for Practical Farming Applications. Smart Agric. Technol. 2024;9:100595.
51. Ahmadi et al. Towards Autonomous Visual Navigation in Arable Fields. arXiv. 2021;2109.11936.
52. Teng et al. Adaptive LiDAR Odometry and Mapping for Agricultural Mobile Robots. arXiv. 2024;2412.02899.
53. Martini et al. Position-Agnostic Autonomous Navigation in Vineyards via Deep Reinforcement Learning. arXiv. 2022;2206.14155.
54. Wisnubhadra et al. Application of Machine Learning in Precision Agriculture using IoT. IEEE ICIEM 2021; pp.34–39.
55. Sharma et al. Machine Learning Applications for Precision Agriculture: A Review. IEEE Access. 2021;9:4843–4873.
56. Liakos et al. Machine Learning in Agriculture: A Review. Sensors. 2018;18(8):2674.
57. Meshram et al. ML in Agriculture Domain: A State-of-the-Art Survey. Artif. Intell. Life Sci. 2021;1:10001
58. BuletinIlmiah Sarjana Teknik Elektro. Precision Agriculture 4.0: IoT, AI, Sensor Networks for Tomato Crop Prediction. 2022; vol.?
59. “Frontiers | Real-Time Cloud Enabled IoT Crop Management Platform.” Frontiers in Plant Science. 2022;1030168.