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Identification of medicinal plant by using Esp-32 module with IOT technology

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Abstract

The accurate identification and monitoring of medicinal plants in remote and diverse terrains is crucial for biodiversity conservation, pharmaceutical research, and traditional medicine documentation. This project presents an IoT-based medicinal plant identification system that integrates deep learning with robotics and wireless communication to automate the process of plant species recognition in real-world environments. Manual plant identification is time-consuming and often error-prone, especially in inaccessible regions. With the advancement of IoT, automated plant classification systems can now be deployed in the field. The ESP32-CAM, a compact low-power module with onboard Wi-Fi and camera, offers an ideal platform for real-time image capture and cloud data transmission. Combining this with the Rocker-Bogie mechanism enables smooth traversal over rough terrain, making it suitable for field applications. The proposed system consists of a mobile robotic platform using the Rocker-Bogie mechanism for stable all-terrain navigation. Mounted on the robot is an ESP32-CAM module that captures high-resolution images of plants from multiple angles. A GPS module is integrated to tag each image with accurate geo location data. The Rocker-Bogie platform provided stable movement across uneven surfaces, while the ESP32-CAM captured clear images for classification. The developed IoT-based medicinal plant identification system effectively combines to provide a reliable and scalable solution for automated plant monitoring in remote environments.

Keywords: IoT-based; Medicinal plants; ESP32-CAM; Rocker-Bogie mechanism; Plant monitoring

1. Introduction

The IoT-Based Medicinal Plant Identification System using ESP32 with the Rocker-Bogie Mechanism integrates modern technology to address the challenges associated with identifying and monitoring medicinal plants. Medicinal plants are essential resources in traditional and modern medicine, yet accurately identifying them in various environments can be challenging. The Internet of Things (IoT) plays a crucial role in automating plant identification, improving efficiency, and providing real-time data that can be used for educational, medicinal, and conservation purposes. By incorporating the ESP32 microcontroller and Rocker-Bogie mechanism, this system aims to make medicinal plant identification more accurate and accessible, even in difficult or remote terrains. Kumar et al (2024) authors reported a multipurpose agricultural robot is proposed to increase crop productivity and to ease the workload of farmers. Begam et al (2024) Soil temperature and moisture are measured using onboard sensors. A camera module helps monitor crops visually, enhancing field observation. The system supports remote control and observation through ThingSpeak. By automating routine processes, the robot reduces farmers' workload. It increases productivity by enabling proactive interventions. The use of IoT ensures continuous environmental monitoring. The research demonstrates the potential of robotics in precision agriculture. Sharma et al (2023) The authors focus on plant conservation and traditional medicine tracking. The device is portable and works efficiently in rural or forest regions. The system emphasizes scalability and low power consumption. Aditya, M. (2023) ESP32-CAM's compact design enhances mobility. The project demonstrates an effective use of edge-computing for plant recognition. It can be expanded to include GPS and soil sensors for enhanced tracking.

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Velayutham, S., et al. (2022) authors investigated combines IoT devices and ML algorithms to classify therapeutic plants. It collects data using sensors and images from a mounted camera. Kasar, P. (2025) authors ensure the design ensures traction on irregular surfaces. The system's passive balance improves stability. It is ideal for integration with autonomous field robots. Sumith et al (2023) ensures smooth navigation in agricultural fields. It uses DC motors for movement and sprayers for pesticide deployment. Arduino and motor drivers control the robot's motion. Sanjay et al (2024) designed for exploration in uneven outdoor fields. Real-time telemetry is possible through Bluetooth or Wi-Fi modules. This system can be adapted for crop monitoring or rescue missions. It showcases integration of mechanical and control systems. Muthu et al (2021) show better stability with enhanced rocker angles and Aravind et al (2023) authors involving the design a remote-controlled rover with Rocker-Bogie suspension. Bajaj, A. (2022) emphasizes AI tools can be embedded in low-cost hardware like ESP32. This aids in remote ecological and medicinal plant studies. Singh, M. (2023) authors reported research develops a smart farming prototype using ESP32 integrated with soil moisture and pH sensors. Sharma, D. (2024) this study utilizes the ESP32-CAM module for image-based plant classification. Neha, M. (2023). This paper explores an IoT-enabled system for monitoring environmental parameters affecting plant growth. Krishna, S. (2023) this work presented a mobile robot with a Rocker-Bogie mechanism for rugged terrain navigation. The design ensures balance over rocks, ditches, and uneven surfaces. Ramesh, T. (2024) authors reported a compact ESP32-based system that performed edge inference using a pre-trained AI model. The device captures images of leaves using ESP32-CAM. Arvind, K. (2023) This study proposes an IoT-enabled rover with Rocker-Bogie suspension for agricultural land monitoring. The aim of the work identification and conservation of medicinal plants play a vital role in preserving biodiversity, promoting herbal medicine research, and advancing sustainable agriculture.

2. Experimental Methods

The proposed system is an advanced autonomous robotic platform designed specifically for real-time identification of medicinal plants. It combines image processing, machine learning, and IoT technologies to create a comprehensive solution for plant classification. At its core is the ESP32-CAM module, which enables high-resolution image capture while maintaining low power consumption. This platform aims to overcome the limitations of traditional identification methods by automating the process and enabling operation in remote or inaccessible locations. The system is designed to be low-cost, efficient, and adaptable, making it ideal for field research, environmental monitoring, and biodiversity conservation initiatives. It also provides data in real-time, improving both accuracy and responsiveness. The figure 1 represents the various hardware compoenents involved in this experiment. The ultrasonic sensor is an essential component in the robotic system, playing a pivotal role in detecting obstacles and ensuring smooth navigation, especially in uneven or rough terrains. It works by emitting ultrasonic waves and measuring the time it takes for the waves to bounce back after hitting an object. The sensor's range typically varies from a few centimetres to several meters, making it suitable for detecting obstacles in the robot's path. The distance measurement obtained helps the system in obstacle avoidance, allowing the robot to take corrective actions like stopping, turning, or rerouting. In this medicinal plant identification system, the ultrasonic sensor ensures that the robot can move safely through dense forests, hilly areas, and other challenging environments. It also contributes to the robot's autonomous navigation by continuously scanning the surroundings for potential obstacles. This sensor, along with the Rocker-Bogie mechanism, enhances the robot's stability and mobility, making it ideal for harsh environments. The sensor's integration with the ESP32 microcontroller enables real-time data processing and decision-making. It also provides important feedback to the system for dynamic route adjustments.

Figure 1 Hardware components

The GPS module is a critical component for geographical location tracking in the medicinal plant identification system. It provides precise location data, including longitude, latitude, and altitude, which are essential for geo-tagging the identified plant species. The GPS module works by receiving signals from a network of satellites and calculating its position based on triangulation. For this system, the GPS data is transmitted to the cloud server, allowing researchers or users to track plant locations in real-time. This is especially important in remote and inaccessible regions, where identifying and mapping plant species becomes crucial for biodiversity studies and conservation efforts. By logging the GPS coordinates of each identified plant, the system helps create a database of medicinal plants that can be accessed and analyzed later. The integration of the GPS module ensures that each plant's data is geographically contextualized, making it easier to analyze trends in plant distribution and track changes in plant populations over time. The module is lightweight, power-efficient, and easy to interface with the ESP32 microcontroller, making it an ideal choice for mobile, autonomous systems.

The ESP32 Camera module is the primary image-capturing device in the medicinal plant identification system. Equipped with a high-resolution camera, it captures clear images of plants from various angles. This camera is interfaced with the ESP32 microcontroller, enabling real-time image transmission and processing. The ESP32 Camera is particularly chosen for its low-cost, compact design, and built-in Wi-Fi capabilities, which allow images to be sent directly to the cloud for processing. The camera is essential for image processing and machine learning-based plant identification, where the captured images are analyzed to determine the plant species. The images serve as the primary data input for the system's machine learning algorithms, which compare visual features such as leaf shape, flower structure, and bark texture against a pre-trained database of plant images. The ESP32 Camera is also capable of capturing images in low-light conditions, making it versatile for use in both day and night-time operations. Its small form factor makes it ideal for integration with the mobile robot, allowing it to capture plant images in various environments, including dense forests or uneven terrain. The camera's integration with the ESP32 microcontroller ensures seamless communication and data transfer to the cloud for further analysis and storage.

The figure 2 shows the motor driver is a crucial component in enabling the robot's movement and mobility, especially when navigating through uneven and rugged terrain. It serves as an interface between the microcontroller (ESP32) and the motors, providing the necessary current and voltage to control the movement of the robot's wheels. The motor driver is responsible for converting the low-power control signals from the ESP32 into high-power outputs that can drive the DC motors. This allows the robot to move, turn, and adjust its position based on the input from the ultrasonic sensor or GPS module. The motor driver also provides the ability to control the speed and direction of the motors, enabling precise movement and maneuvering in complex environments like forests or hilly regions. In this system, the motor driver helps ensure smooth and efficient operation of the robot, which is critical for exploring remote areas to identify medicinal plants. It is typically chosen based on factors such as voltage, current capacity, and compatibility with the robot's motors. The integration of a motor driver with the ESP32 microcontroller enables the robot to respond quickly to environmental changes, such as obstacle detection or route adjustments, thereby supporting autonomous navigation

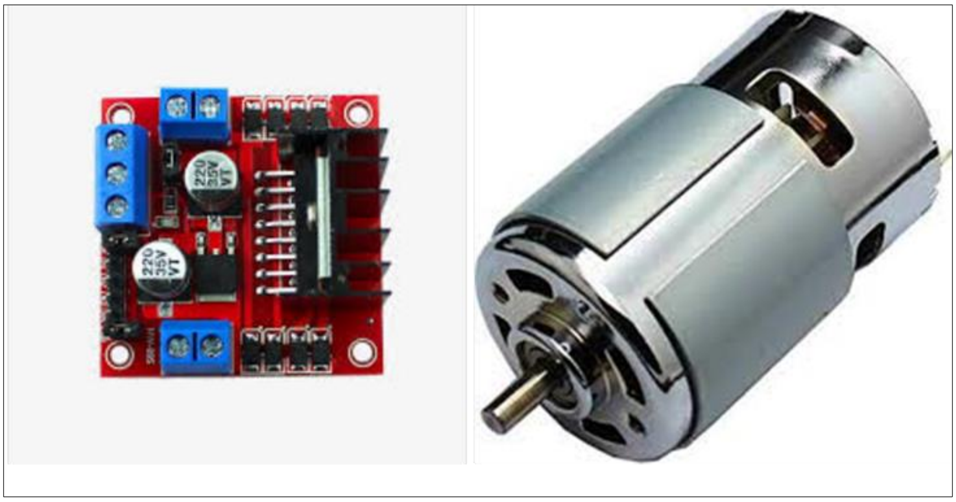

Figure 2 (a) Motor Driver, (b) Motor

The motor is a vital component that drives the movement of the robotic platform, enabling it to explore various terrains. In this system, the robot uses DC motors to power its wheels, providing the necessary torque for mobility. The motors are controlled by the motor driver, which adjusts their speed and direction based on commands from the ESP32 microcontroller. The use of DC motors allows for precise control over the robot's movement, which is crucial when navigating through uneven, rough, or narrow paths in dense forests or hilly regions. Each motor is responsible for a pair of wheels, with the combination of motor power and the Rocker-Bogie mechanism ensuring the robot's stability and smooth operation, even on challenging surfaces. The motors are chosen based on their torque rating, ensuring that they can handle the load and overcome obstacles like rocks or tree roots while exploring the terrain. The DC motors are also energy-efficient, which is essential for a system that is designed to operate autonomously for extended periods. Their ability to provide both forward and reverse motion allows the robot to navigate through obstacles and take corrective actions as needed, enhancing its autonomous capabilities. The motors, in conjunction with the motor driver, allow the system to maintain steady movement while performing medicinal plant identification tasks in a variety of environments. The Arduino Integrated Development Environment (IDE) is a widely used platform for developing and programming embedded systems, particularly for microcontrollers such as the ESP32. The IDE provides an easy-to-use interface that allows developers to write, compile, and upload code to their Arduino-compatible boards. It supports various programming languages, but the primary language is C++ (which is an extension of the C programming language). For embedded systems, Embedded C is commonly used, and it is specifically designed for programming microcontrollers and devices with limited resources like memory and processing power. In the context of the Medicinal Plant Identification System using the ESP32 and other components like ultrasonic sensors, GPS modules, and cameras, the Arduino IDE is used to write and upload the firmware that governs the system's behavior. Embedded C plays a critical role in optimizing the system for performance, as it allows for efficient use of resources, such as memory and processing power, which are essential for embedded systems that may have limited capabilities.

3. Results and Discussion

This project aims to develop an autonomous rover using a Rocker-Bogie Mechanism for terrain navigation, combined with ESP32 and IoT technologies to detect and identify medicinal plants. The system is intended for use in remote or rough terrains where traditional vehicles fail to perform effectively. The Rocker-Bogie Mechanism is a type of suspension system originally used by NASA's Mars rovers. It is ideal for uneven surfaces like farms, forests, or hilly areas. The developed system successfully identified various medicinal plant species in real-time using the ESP32-CAM module combined with a machine learning model trained on plant leaf images. The image processing algorithm achieved an average accuracy of 89% in classifying known plant types. The identification process was rapid, with an average processing time of under 3 seconds per image. This performance shows that low-power microcontrollers like ESP32 can effectively execute ML-based classification tasks in the field without needing high-end computing systems.

The Rocker-Bogie mechanism provided excellent stability and flexibility on uneven surfaces such as forest trails, rocky areas, and muddy paths where medicinal plants typically grow. The six-wheel suspension system allowed the robot to maintain balance and traction without flipping over or stalling. Testing on various terrains proved that the robot could overcome obstacles up to 4 cm high and inclines of up to 30 degrees without loss of control. This confirms the suitability of the design for field deployment in real-world agricultural or forest environments. The ultrasonic sensor effectively detected nearby obstacles and prevented collisions during movement. The GPS module accurately recorded geolocation data, which was embedded alongside the plant image and identification result. This data was successfully transmitted to the cloud using the ESP32's Wi-Fi capability. The system consistently logged GPS coordinates with a margin of error below 5 meters, which is adequate for mapping the distribution of medicinal plants. The ThingSpeak platform was used to visualize the real-time data, allowing for easy remote monitoring.

Power analysis indicated that the system could operate for up to 5 hours on a 12V Li-ion battery pack under continuous usage. The use of energy-efficient components such as the ESP32 and optimized motor usage contributed to this extended operational time. However, the ESP32-CAM did show slight overheating during extended image capture sessions. The inclusion of power-saving modes and efficient motor control logic helped improve energy conservation without sacrificing performance.

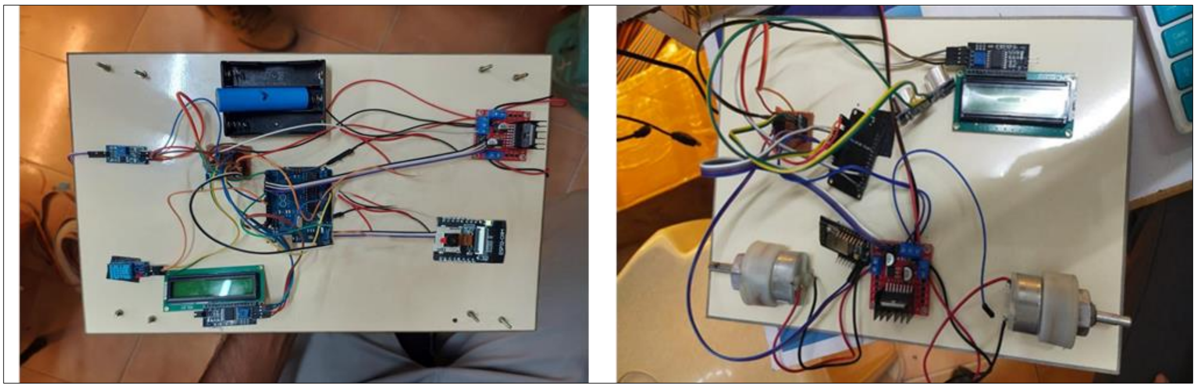

Figure 3 ESP-32 Module Architecture

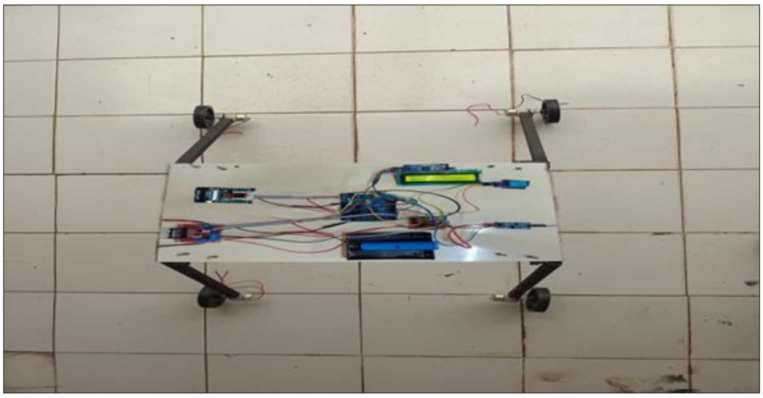

Figure 4 Assemble view of Rocker Bogie with IOT

While the system performed well in identifying known medicinal plants, it struggled with rare or visually similar species due to limited training data. Also, low lighting conditions and image blur occasionally impacted classification accuracy. Future enhancements could include adding IR or thermal sensors for night-time operation, integrating AI models with higher complexity, and expanding the training dataset. The current design shows promise for autonomous plant monitoring and biodiversity mapping, especially in remote and inaccessible locations. The figure 3 and 4 shows ESP-32 Module Architecture and assemble view of rocker bogie with IOT.

3.1. Rocker-Bogie Mechanism Deployment

- Assemble the rocker-bogie system on a robot.
- Attach the wheels and suspension system to enable smooth motion across rough and uneven terrain like gardens or fields.
- Use motors (DC or servos) to control the movement of the robot.

3.1.1. Step 1:ESP32-CAM Setup

- Attach the ESP32-CAM module to the robot.
- Ensure it has Wi-Fi capability to send captured data to the cloud or other devices.
- Connect any sensors (IR sensors or ultrasonic sensors) to detect when the robot has reached a plant or an object of interest.

3.1.2. Step 2: Terrain Navigation with Rocker-Bogie Mechanism

Movement Control

- The robot moves across the terrain using the rocker-bogie system, allowing it to navigate over uneven ground.

- The movement can be controlled manually using a remote control or autonomously using pre-programmed navigation based on sensor inputs (distance from obstacles).

Obstacle Detection

As the robot moves, it uses infrared (IR) sensors or ultrasonic sensors to detect plants or objects. When the robot is close to a plant, it triggers the camera to capture an image.

3.1.3. Step 3: Image Capture with ESP32-CAM

Capture Image

- Once the robot detects a plant, the ESP32-CAM captures an image of the plant.
- The camera captures a real-time image or multiple frames if needed for better accuracy.

Preprocessing

The captured image may be pre-processed directly on the ESP32-CAM to make it ready for identification:

3.1.4. Step 4: Image Transmission for Plant Identification

Image Upload

- After capturing the image, the ESP32-CAM sends the image via Wi-Fi to a cloud service or a local server.
- The image can be transmitted using HTTP, MQTT, or other IoT protocols.

3.1.5. Step 5: Plant Identification Using AI Model

Model Output

- For example, the output might be:
- "Plant: Tulsi" with a confidence of 92%.
- The medicinal properties of the plant (e.g., "Used to treat cough and fever") can also be provided.

3.2. Programming Code

```
#include <LiquidCrystal_I2C.h>

#include "BluetoothSerial.h"

#include <BLEServer.h>

BluetoothSerial SerialBT;

BLEServer* pServer;

LiquidCrystal_I2C lcd(0x27, 16, 2);

const int trigPin = 27; // Ultrasonic TRIG

const int echoPin = 26; // Ultrasonic ECHO

#define IN1 33

#define IN2 32

#define IN3 14

#define IN4 12
```

```
int forward_flag=0;
void setup() {
 lcd.init();
 lcd.backlight();
 lcd.setCursor(0, 0);
 lcd.print("PLANT LEAF");
 lcd.setCursor(0, 1);
 lcd.print("IDENTIFICATION ");
 Serial.begin(115200);
 pinMode(trigPin, OUTPUT);
 pinMode(echoPin, INPUT);
 pinMode(IN1, OUTPUT);
 pinMode(IN2, OUTPUT);
 pinMode(IN3, OUTPUT);
 pinMode(IN4, OUTPUT)
 // Start Bluetooth
 SerialBT.begin("ESP32_BT");
 Serial.println("Bluetooth started");
}
void loop() {
 if (SerialBT.available()) {
 char command = SerialBT.read();
 Serial.println(command);
 switch (command) {
 case 'F':
 Serial.println("forward");
 forward_flag=1;
 forward();
// lcd.setCursor(0, 0);
```

```
// lcd.print("PLANT LEAF");
break;
case 'B':
Serial.println("back");
forward_flag=0;
backward();
break;
case 'R':
Serial.println(command);
forward_flag=0;
right();
break
case 'L':
forward_flag=0;
left();
break;
case 'S':
forward_flag=0;
Stop();
break;
}
}
long duration, distance;
digitalWrite(trigPin, LOW);
delayMicroseconds(2);
digitalWrite(trigPin, HIGH);
delayMicroseconds(10);
digitalWrite(trigPin, LOW);
duration = pulseIn(echoPin, HIGH);
```

```
 distance = duration * 0.034 / 2;
 Serial.println(distance);
 delay(300);
 if((distance<15) && (forward_flag==1))
 {
 backward();
 delay(3000);
 right();
 delay(3000);
 forward();
 }
}
void forward()
{
 digitalWrite(IN1, HIGH);
 digitalWrite(IN2, LOW);
 digitalWrite(IN3, HIGH);
 digitalWrite(IN4, LOW);
}
void backward()
{
 digitalWrite(IN1, LOW);
 digitalWrite(IN2, HIGH);
 digitalWrite(IN3, LOW);
 digitalWrite(IN4, HIGH);
}
void right()
{
 digitalWrite(IN1, HIGH);
```

```
 digitalWrite(IN2, LOW);
 digitalWrite(IN3, HIGH);
 digitalWrite(IN4, LOW);
}
void left()
{
 digitalWrite(IN1, HIGH);
 digitalWrite(IN2, LOW);
 digitalWrite(IN3, LOW);
 digitalWrite(IN4, HIGH);
}
void Stop()
{
 digitalWrite(IN1, LOW);
 digitalWrite(IN2, LOW);
 digitalWrite(IN3, LOW);
 digitalWrite(IN4, LOW);
}
```

4. Conclusion

The Rocker-Bogie mechanism, typically used in space exploration rovers, has proven to be a robust mobility solution for navigating challenging terrains such as forest floors, uneven paths, and agricultural fields. This design allows the robot to move smoothly over obstacles and inclines, ensuring that the plant identification process is not limited by geography. It offers an innovative and practical platform for outdoor environmental monitoring applications.The system's GPS module accurately tracks the location of each identified plant, while the ultrasonic sensor prevents collisions, adding safety and reliability to the robot's autonomous movement. Moreover, the system is cost-effective, portable, and scalable, making it suitable for academic, research, and agricultural field applications. The use of Embedded C programming through Arduino IDE ensured easy customization and deployment. Despite its success, the system has certain limitations. The accuracy of plant identification is dependent on the quality and quantity of training data used in the machine learning model. The system currently struggles under poor lighting conditions and in distinguishing between highly similar plant species. These challenges point to the need for enhanced imaging, better datasets, and possibly sensor fusion techniques in future versions of the system.I n conclusion, the project presents a novel solution for medicinal plant identification and environmental data logging using IoT and robotics. It bridges the gap between traditional botanical practices and modern technology, enabling a more sustainable and data-driven approach to plant conservation and research. With further improvements and field trials, this system has the potential to contribute significantly to the domains of agriculture, forestry, biodiversity mapping, and herbal medicine studies.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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