Original Article

Re-forestation using robotic vehicle

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Abstract - Research on automated agriculture robotic vehicle is a crucial aspect of advancing the agriculture industry, particularly in India, where agriculture serves as the backbone of the economy and significantly contributes to GDP. This paper introduces a novel approach to development of Re-forestation using "self-driven" robotic vehicle integrated with software and hardware components. This primary aim of this research is to enhance the productivity and sustainability in reforestation practices by leveraging advanced technologies like a robotic vehicle and Machine Learning Algorithms. Focused on technologies aspects of agriculture, this research paper presents an integrated system consisting of two main functionalities: 1)Robotic vehicle that performs various farming activities that assist farmers such as ploughing, sowing , irrigation.2)Crop prediction using live sensors such as temperature , soil moisture and atmospheric pressure .The crops are predicted using the data sensed by these sensors and use Machine Learning Algorithms trained on historical field data.

Additionally this research work helps the beginner farmer in sowing the adaptive crop reducing the man power, enhances planting precision by automated planting system and reduces the chances of crop failures through crop recommendation system. Finally the approach followed in this shows excellent potential for automating the farming practices and crop prediction. In fact, the test was performed on the rice and tomato crops demonstrated the effectiveness of the proposed approach, and the same approach can be used on other crops to achieve the same goal.

Looking ahead, this research offers insights into further developments of automating forest management, accurate yield prediction of recommended crop, and maintaining the ecological balance.

Keywords *- Reforestation, precision farming, crop prediction, Machine Learning Algorithms, self-driven robot, farming practices*

1. Introduction

Agriculture has been a cornerstone of human civilization, to satisfy the basic daily needs. In India, agriculture serves as primary occupation for a large sector of Indian population. Several reasons such as changing weather conditions, depletion of natural resources and pollution has significantly reduced the crop production [1].To address these concerns, there is need to innovate technologies that can enhance productivity and promote sustainable farming practices[2].

Robotics and Machine Learning have evolved in different industries, including agriculture. Both the technologies have solved some of the major concerns such as labor crisis, crop failure, weather unpredictability, declining soil fertility, inefficient resource utilization, crop diseases and pest infestation [3]. Majority of these are caused due to knowledge gaps and lack of proper technologies that can assist farmers [4].

Hence this research introduces an integrated system combining a self-driven robotic vehicle and machine learning algorithms to improve farming and reforestation practices. These technologies can address critical agricultural challenges by automating labor-intensive tasks, improving decision making and increasing efficiency. The proposed system address crop yield prediction, adaptive crop recommendation and large-scale re-forestation using the self-driven robotic vehicle [5].

Automated farming activities- The robotic vehicle automates farming tasks such as ploughing, sowing, irrigation and weed removal , reducing the need of extensive labor and increasing operational precision[6]. Data collected through sensors can be viewed in Blynk IoT [7] Another feature of the system is Suitable crop and yield prediction- By analyzing data through sensors measuring temperature, soil moisture and atmospheric pressure, the system predicts crop suitability and recommend optimal crops to farmers and additionally the farmers can enter the sensed values in the developed web application that predicts the crops and yield considering more features such as Nitrogen, Phosphorus, Potassium, temperature, humidity, pressure, and pH values[8][9].

These technologies not only enhance planting precision but also help farmers adapt to changing environmental conditions, mitigate crop failures, and increase yield. The system's applicability extends beyond conventional agriculture to reforestation efforts, enabling large-scale tree planting and ecosystem restoration with minimal human intervention [10].

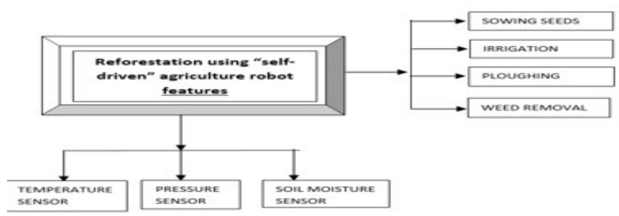

Fig 1 Features of Robot –
Explains about an integrated system for reforestation using a self-driven agricultural robot. Main functionalities are owing seeds, irrigation, ploughing, and weed removal, supported by temperature, pressure, and soil moisture sensors to monitor environmental conditions.

2. Literature Review

1.Songyu Li, Morgan Rossander, Hakan Lideskog (2024).

Proposed a system that performs obstacle detection and providing estimated position to plant planner to function which in turn plan and select planting areas. Looking ahead, future developments for irrigation, ploughing, weeding can be done in the same proposed methodology[6].

2.Michail Moraitis ,Konstantinos Vaiopoulos , Athanasios T.Balafoutis (2022)

Developed an economic robotic system for the automatic monitoring and management of urban gardens. The systems was integrated providing precise movement of its actuator and applying precision irrigation based on specific needs. This system can be further more developed by deploying into farming and forest areas, by increasing its capabilities[4].

3.Abdellatif Moussaid ,Sanaa El Fkihi October 2022)

The main aim of the project was to define an intelligent system for predicting citrus fruit yield before the harvest period using machine learning algorithm trained on historical field data. Though this study shows excellent potential for fruit yield prediction, the same method may not give accurate results for rest of the crops [8].

4.Tylek Pawek, Szewczyk Grzegorz (2023)

The paper presents design solution of the key working unit, which is universal, openable dibble, cooperating with a three-toothed shaft to prepare a planting spot. The solution enables continuous operation of the machine. This system can be future integrated with system for planting and other farming activities such that fully functional system can be deployed in a Forest [10].

5.Joy Iong-Zong Chen and Pisith Hengjinda (2019).

The purpose is to apply an artificial intelligence (AI) to manage the operation of a farm robot. The researchers have designed robot for farming rice and its control system based on AI. The robot can move automatically with the data collected. To complete the operation, power consumption is a major concern [5].

3. Drawbacks of existing methods.

Though there is advancement in technology in agriculture and farming practices, there are drawbacks with respect to the proposed method. Some of the systems focus only on the obstacle detection and planting selection, neglecting other essential farming activities like preparing the soil for optimal seed placement, monitoring soil moisture and providing appropriate amount of water to crops.

Other integrated systems relay on specific planting mechanism (dibble with three-toothed shaft) may limit adaptability to different soil types or terrains.

Some of the systems are limited to urban gardens, adoption for forest or rural farming would require significant modifications, which are not yet explored.

These systems also lack integration of advanced analysis techniques for crop recommendations. Also these systems do not address real-time or live data integration, which is crucial for adaptive prediction systems. Additionally relaying only on the historical data may result in inaccurate prediction in unforeseen natural conditions.

Sensor based monitoring or live monitoring of the environmental conditions to predict the suitable crop and monitoring the crops in real time has not been possible in the existing methods.

4. Problem statement

Reforestation efforts and traditional farming practices face challenges due to labor intensity, inefficiency, and environmental degradation. Current traditional tasks such as ploughing, sowing, irrigation, and weed removal are labor intensive tasks, leading to inconsistent results. Additionally crop failures caused by unpredictable environmental conditions hinder agricultural productivity and sustainability.

Advancements in agriculture and reforestation robots have made notable progress. However, there is a need for more precise solutions. Current systems focus on limited functionalities such as obstacle detection and planting position selection, absence of sensor based real time data monitoring systems, adaption to rural farming and forest reforestation, inability to predict the crop suitable for the weather conditions.

To address these challenges, a need arises for a robotic vehicle that can automate farming practices while ensuring precision and efficiency controlled by RF module. The proposed method automates tasks from the initial phase of crop prediction-Utilizing live environmental data to recommend the suitable crop, preparing the soil for optimal seed placement, planting seeds at precise intervals, and finally monitoring the soil moisture and providing the appropriate amount of water to crops.

This reforestation robot can operate through RF module in diverse terrain, adapt to varying soil and climatic conditions and provide a sustainable farming solution for large-scale planting. It aims to increase the agricultural efficiency, reduce labor dependency, and minimize environmental impact while contributing to forest reforestation.

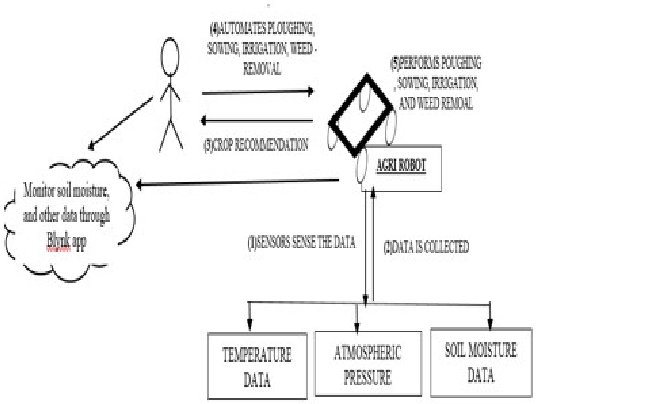

Fig 2 **Flow chart** displays how an agricultural robot collects data from sensors (temperature, atmospheric pressure, and soil moisture), automates tasks like ploughing, sowing, irrigation, and weed removal, and integrates with the Blynk app for monitoring and crop recommendations.

5. Materials and Methods

Reforestation robot address major agricultural issues by automating farming practices and developing an application that can predict the suitable crop using Crop Recommendation System. Following are the major developments:

1) Reforestation robotic vehicle – The hardware setup integrates ESP32 NodeMCU as the central controller and acts as coordinator between multiple processes. ESP32 NodeMCU is beneficial as it has dual-core processor which can handle multiple tasks concurrently such as processing the sensor data, controlling motors and managing communications. Additionally, it solves the problem of cost and energy as they are cost and energy efficient.

Servo motors are utilized for ploughing and seed sowing as it has control of angular or linear position, and has compact size. Removal of unwanted plants which hinder the growth of the crops, this is done with the help of DC motor.

Sensors like soil moisture, DHT sensor for temperature detection, and BMP sensor for pressure provide real-time environmental data. This data can be further utilized in Crop Recommendation System. Soil moisture can be detected and real time monitoring of the moisture levels can be done. When there is an indication saying the soil is dry, the system has automated irrigation system which turns on. All the sensor data are collected and stored in Blynk app. Sensor monitoring and control can also be done through the same application.

The system uses RF communication to control a robot designed for field mobility. They work on the principle of transmitter and receiver. By combining automation and remote mobility, the methodology reduces manual labor, improves precision and enhances efficiency in agricultural operations, making it a robust solution for both rural, urban farming and forest reforestation.

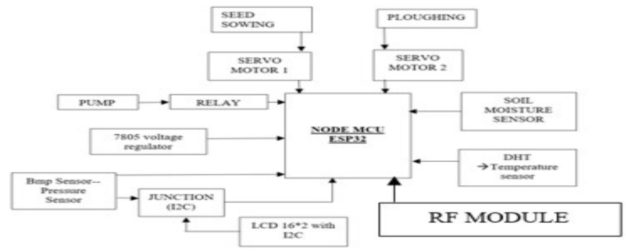

Fig 3. Hardware setup

Fig 3 Hardware setup uses an ESP32 Node MCU to control seed sowing, ploughing (via servo motors), and irrigation (via a pump and relay) while monitoring soil moisture, temperature, and pressure sensors, with an RF module for communication and an LCD for display.

2)Crop and Yield Recommendation system: Two ways of obtaining the crop recommendation is integrated in the system. One is the robotic vehicle analyses the temperature and humidity and based on the condition it recommends the crops, other is through an application, the end user is required to enter the data sensed by the sensors manually into the application, wherein it uses machine learning algorithm to predict the crop and the yield. The application uses random forest classifier to build a machine learning model for crop recommendation. Feature values are standardized using Standard Scaler, which ensures that the data is centered and scaled for optimal performance. This prevents features with larger ranges from dominating those with smaller ranges. Evaluation metrics to measure the model's performance are based on accuracy score and classification report (precision, recall, F1-score) .This provides an understanding of how well the model is performing on unseen data. For prediction, input features (e.g., soil properties, weather conditions, etc.) are first scaled using the previously saved scaler.

For yield prediction, random forest regressor with a pipeline is used to predict the amount of yield. One-hot encoding, which coverts categorical variables to binary variables are used to process the data. Interactive prediction and pipeline usage are used for efficient model management.

6. Results and Discussion

The results of the system highlight effectiveness in automating essential agricultural tasks, aligning with the growing need for automated agricultural practises and resource optimization. The use of NodeMCU ESP32, with integration of RF module , not only ensured seamless control and data monitoring but also demonstrated its cost-effectiveness and scalability compared to traditional microcontrollers. The precise operation of servo motors in ploughing and seed sowing underscores their suitability for agricultural automation, while real-time data from soil moisture and environmental sensors enabled smart irrigation, reducing water usage and promoting sustainability. The RF-controlled robotic mobility further emphasized the potential for human intervention in inaccessible or hazardous areas, ensuring flexibility and safety. These findings corroborate existing knowledge on the benefits of automation and IoT in agriculture, while also showcasing how modular, energy-efficient systems can improve productivity and reduce labor dependency. The system's adaptability to diverse field conditions and its potential integration with Blynk IoT app suggest broader implications for scalable smart farming solutions, bridging the gap between traditional practices and modern technological advancements in agriculture.

Random forest classifier is a supervised machine learning algorithm used for classification tasks. It is based on the concept of ensemble learning, where multiple decision trees are trained on random subsets of the data, and their outputs are aggregated to make the final prediction. Hence it is best suited for crop prediction system for accurate results. The Random Forest Regressor is a supervised machine learning algorithm used for regression tasks. Like the Random Forest Classifier, it also uses an ensemble of decision trees hence, best suited for yield prediction.

Sl.no	Sample of crop recommendation by robot		
	Predicted crop	***temperature***	***pressure***
1	Wheat	0-15	>1000
2	Maize	15-25	<1000
3	Beans	15-25	>1000
4	Tomatoes	25-35	<1015
5	Peppers	25-35	>1015
6	Rice	>35	>1200

Table 1.1 Crop Recommendation criteria

7. Conclusion

The system effectively automates agricultural operations such as ploughing, sowing, irrigation, and weeding and ensures precise and consistent movements enabling uniform field coverage. Real-time monitoring of live environmental data including soil moisture, temperature, and pressure allows optimum utilization of resources, with irrigation pump activity only when necessary, and minimizing water wastage. Real-time feedback mechanism through Blynk IoT app enhances system transparency and user control. . Using NodeMCU ESP32, sensors, and servo motors, it demonstrated cost-effective and energy-efficient smart farming, with real-time environmental monitoring optimizing resource utilization. The RF-controlled robot added flexibility for field navigation, making the system adaptable and scalable. The robot also shows seamless field navigation. The system has enhanced the efficiency of agricultural tasks.

Crop recommendation and yield prediction can protect the crops from crop failures through early detection. The system integrated with crop and yield recommendation system can suggest the suitable crop and same from crop failures. Crop recommendation suggests crops that can be best grown in the given agricultural conditions considering temperature, pressure, pH, Nitrogen, Phosphorus, humidity, rainfall. Yield predictions are also done on machine learning algorithms.

8. Future improvements

For future improvements, autonomous navigation using GPS or machine vision and cloud-based data analytics can be incorporated for larger-scale applications. Adding sensors like pH and nutrient monitors could enable comprehensive soil analysis. This system provides a robust foundation for advancing precision agriculture and sustainable farming technologies. Crop recommendation and yield prediction system can be improved by incorporating more features and predicting more accurate results

Conflicts of Interest

The author(s) declare(s) that there is no conflict of interest regarding the publication of this paper."

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