Design and Development of an Autonomous Agri- Rover for Precision Fertilization

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Abstract: People usually put fertilizer on their farms in a way without thinking about the different conditions of the soil. This can be a waste of resources. Can also harm the environment. To fix this problem we made a machine called an autonomous fertilization rover that uses artificial intelligence to help with farming. The machine uses information about the soil that it gets from sources like how much nitrogen, phosphorus and potassium are in the soil. It then uses a kind of computer program to figure out how much of each nutrient the soil really needs.The machine compares the amount of nutrients the soil already has to the amount it needs. That tells it when to put more fertilizer on the soil. The rover moves around the farm on a path and uses special sensors to find the plants. When it finds a plant it puts fertilizer on it using a pump that is controlled by a tiny computer called an ESP32 microcontroller. We tried out the machine. It worked really well. It put the amount of fertilizer on the soil did not waste any and made the whole process more efficient. The machine also has a website that lets people watch what it is doing and save information about how it is working. This machine can really help farmers use technology to make their farms more modern, efficient and good for the environment. Autonomous fertilization rover can be a help, to farmers who want to use autonomous fertilization rover and artificial intelligence to make their farms better.

Keywords: Precision Agriculture; Machine Learning; Autonomous Rover; ESP32; Smart Farming

I. INTRODUCTION

Taking care of the nutrients in the soil is really important for growing food and keeping the soil healthy. Usually farmers put fertilizer over the field without checking if the soil really needs it. This means they use too much fertilizer in some areas and not enough in others. It costs farmers a lot of money. It is also bad for the environment.

New technologies like machine learning and robotics are being used to make farming better. Machine learning looks at the soil and figures out how much fertilizer it needs [3]. This helps farmers put the right amount of fertilizer on their fields. Robots can plant seeds and spray fertilizer, which saves farmers time and makes sure everything is done correctly [1], [4]. There are also sensors that can check the soil and plants in real time. These sensors can even tell if the plants are not getting enough nutrients [2], [5].

Most of the systems that are available only do one or two things. They check the soil or they help with farming tasks. They do not do everything that farmers need to put fertilizer on their fields in the best way.

So a new machine is being proposed. It is like a robot that can move around the field on its own and put fertilizer where it is needed. It uses sensors to check the soil and a kind of computer program to decide how much fertilizer to use [3]. The machine follows a path and puts fertilizer in the right spots.

This new machine can help farmers use fertilizer in a better way. It reduces waste and helps the environment. It also helps farmers grow food while taking care of the earth. The machine is really useful for farmers because it helps them use fertilizer in the best possible way, which is good for the environment and helps them grow more food [1]–[5].

II. LITERATURE REVIEW

The use of technology in farming has changed a lot over time with the introduction of precision farming methods. At first people were looking at ways to make farming easier through automation and using machines. These days technology like machine learning, the Internet of Things (IoT), and robots has made farming smarter and more data-driven [1], [2].

Many researchers have explored using robots and artificial intelligence to improve farming. They proposed autonomous farming systems that use robotics and AI to reduce human effort and increase efficiency [1], [6]. They also developed IoT-based solutions to monitor environmental conditions and support decision-making in agriculture [2].

Machine learning has been widely used in farming to understand crop requirements and improve precision agriculture. Studies show that machine learning can analyze agricultural data and help in nutrient management and decision-making [3]. Robots have also been developed to perform farming tasks such as seed planting and field operations, demonstrating that automation can improve agricultural efficiency [4], [6].

Recently, researchers have focused on technologies that can detect plant health and nutrient deficiencies. These systems use advanced sensors and imaging techniques to monitor crops and support farming decisions [5], [8]. High-resolution imaging techniques have also been used to detect nitrogen deficiency in crops such as corn [7]. However, most existing systems focus on a single aspect such as monitoring, prediction, or automation, and do not provide a complete solution for optimal fertilizer application.

To address these limitations, the proposed system integrates machine learning, autonomous navigation, IoT-based monitoring, and controlled fertilizer spraying into a single platform. It combines advancements in precision agriculture, machine learning, and IoT to develop an efficient solution for optimal fertilizer usage and improved farming practices [1]–[8].

Table 1. Comparison of Existing Work with Proposed System

Ref	ML/AI Used	IoT Monitoring	Autonomous Navigation	Targeted Fertilization
[1]	Yes	No	Yes	No
[2]	No	Yes	No	No
[3]	Yes	No	No	No
[4]	No	No	Yes	No
[5]	No	Yes	No	No
[6]	No	No	Yes	No
[7]	Yes	No	No	No
[8]	Yes	No	No	No
This Work	Yes	Yes	Yes	Yes

III. SYSTEM METHODOLOGY

The proposed system uses machine learning and robotics to put the amount of fertilizer in the right place. It has four parts: collecting data about the soil, figuring out how much fertilizer the soil needs, moving the machine to the right spot, and spraying the fertilizer.

A. Collecting Soil Data

The system gets information about the soil from a website or database. This information tells us about the soil's condition and we use it to decide what to do next. We often use machines that can connect to the internet to keep an eye on the soil [2].

B. Figuring Out How Much Fertilizer Is Needed

We use the information we collected to decide how much fertilizer the soil needs. The system uses a kind of computer program to figure this out. It looks at how much fertilizer the soil already has and how much it needs and then it tells us how much more fertilizer we need to add [3].

C. The Machine: How It Moves

The system uses a special kind of computer called an ESP32 controller. It also has a motor driver, a relay module, special sensors, and a pump. All of these parts are attached to a machine that can move around. The machine follows a path and uses sensors to know where it is going. We use a line on the ground to help the machine know where to go and there are special marks on the line that tell the machine where the plants are. This kind of machine can do things automatically. It helps us save time and effort [1], [4], [6].

D. Spraying Fertilizer

When the machine gets to a plant it sprays fertilizer. The machine knows how to spray the fertilizer based on how much the soil needs. The pump that sprays the fertilizer is very good at giving the right amount so we do not waste any fertilizer [5], [7].

E. How The System Works

The system works in these steps:

1. We collect information about the soil
2. We use machine learning to figure out how much fertilizer the soil needs
3. We calculate how much fertilizer is missing
4. The machine moves to the spot using special sensors
5. The machine sprays fertilizer where it is needed

This way of doing things helps us use fertilizer in an efficient way and it supports a kind of farming that is very precise and efficient. The proposed system uses machine learning and robotics to put the amount of fertilizer in the right place and it has four main parts: collecting data about the soil, figuring out how much fertilizer the soil needs, moving the machine to the right spot, and spraying the fertilizer, which is all part of the machine learning and robotics system [1]–[8].

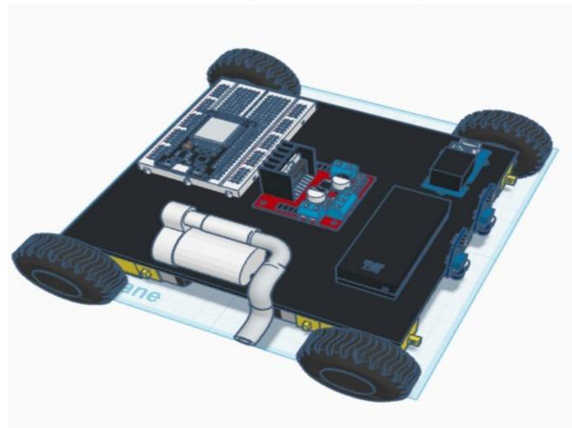


Figure 1. 3D model of the proposed system

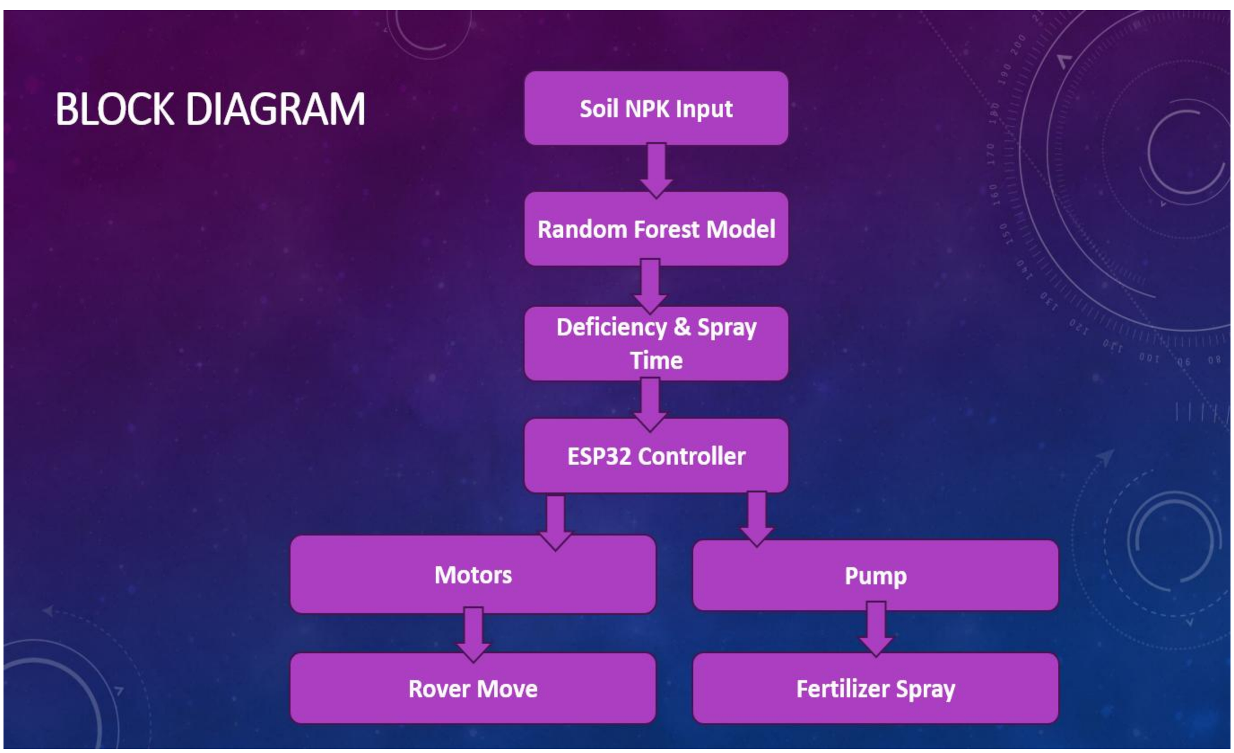
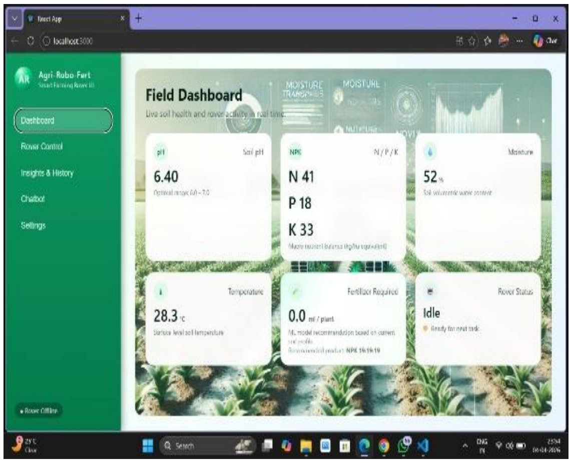


Figure 2. Block diagram of the system.



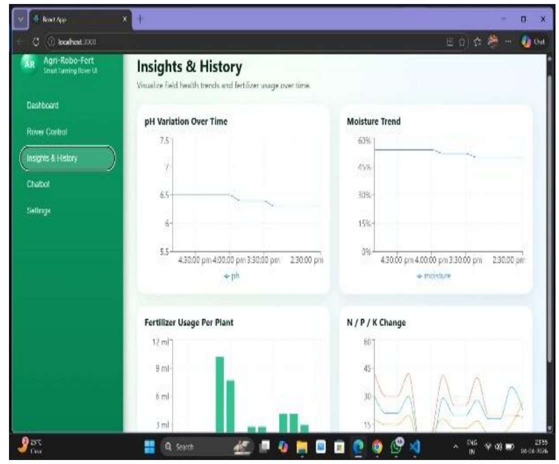


Figure 3. shows the web-based interface used for entering soil values and viewing system outputs.

IV. RESULTS

The rover successfully followed the path and detected plant locations. The system applied fertilizer only at required points [11]. The spray duration matched the calculated values, resulting in controlled fertilizer usage. The web interface displayed input, output, and stored data correctly [12].

V. DISCUSSIONS

The results show that the system can put fertilizer on the soil when it is really needed not just using the amount everywhere. The system uses a machine learning model to figure out how nutrients the soil needs and that helps make good decisions. The rover goes along a path and only puts fertilizer on the plants that need it which makes it more accurate. The pump only works for an amount of time so it does not put too much fertilizer. The web interface is also very useful because it makes it easy to add data and look at old records. The system works well and it shows how using machines and making decisions based on data can make farming better. [11]

VI. CONCLUSIONS

1. The work addresses the problem of inefficient fertilizer usage caused by uniform application methods. The motivation was to develop a system that can apply fertilizer based on actual soil nutrient requirements.
2. The system uses a Random Forest machine learning model to predict required nutrient values. An autonomous rover controlled by ESP32 is used for navigation and fertilizer spraying.
3. The results show that the system can apply fertilizer only at specific plant locations, reduce wastage, and improve efficiency. The integration of machine learning and automation makes the process more accurate and reliable.
4. The system currently depends on externally measured soil data and predefined paths for navigation. In future, real-time soil sensors and advanced navigation methods can be added to improve performance and make the system suitable for large-scale farming.

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