BHARATI VIDYAPEETH'S
COLLEGE OF ENGINEERING, KOLHAPUR.

BACHELORS IN TECHNOLOGY
DEPARTMENT OF ELECTRONICS & TELECOMMUNICATION ENGINEERING

A SYNOPSIS

ON

Soil Analyser with AI Based Crop and Fertiliser Recommendation System

SUBMITTED BY

Siddharth Dilip Patil
Siddhesh Kamalakar Sutar
Harsh Sanjay Randive

UNDER THE GUIDANCE OF

Mr.R.R. Suryawanshi

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Soil Analyser with AI Based Crop and Fertiliser Recommendation System

Introduction

The Soil Analyser with AI Based Crop and Fertiliser Recommendation System is an advanced device designed to innovate soil management in agriculture. This project aims to provide farmers and agricultural professionals with a tool that analyses essential soil nutrients (like Nitrogen, Phosphorus, Potassium and more) and provide AI-based recommendations on optimal crops and fertilisers based on real-time soil data.

This system helps to bridge the gap between traditional farming practices and modern precision agriculture. By using IoT sensors, the device ensures continuous monitoring of soil conditions, enabling farmers to make data-driven decisions that improve crop yield and soil health.

With the capability to detect micronutrient deficiencies and soil pH imbalances, the device ensures a more detailed soil analysis than many existing solutions. Furthermore, the AI system continuously learns from data collected across different terrains and conditions, offering increasingly accurate recommendations over time. This adaptability makes it suitable for a variety of crops, farming scales, and geographical regions.

The cloud-based platform also stores historical soil data, enabling long-term tracking of soil quality, which helps farmers implement sustainable farming practices. The ability to manage soil health with such precision will not only optimise fertiliser use but also help in reducing environmental impacts, such as soil degradation and excessive fertiliser runoff. The system's mobile app ensures that farmers can access these insights on the go, making it easy to adapt their farming strategies as needed.

This project will be particularly useful for small scale farmers, agricultural businesses, and researchers, enabling smarter decisions for crop management and soil care, enhancing food security and environmental sustainability.

Literature Review

The paper by Harshal M. Khairnar and Sangeeta S. Kulkarni titled Automated Soil Macro-Nutrient Analyser using Embedded Systems [1] presents a novel system for measuring soil nutrients (NPK) using colorimetry and embedded systems. The system is effective in reducing time and human errors associated with traditional soil testing methods. However, its limitation lies in its focus on macro-nutrient analysis only, lacking support for micro-nutrient detection, which could be needed in some agricultural practices.

The study by Amrutha A., Lekha R., and A. Sreedevi focuses on an automated soil nutrient detection and fertiliser dispensing system [2]. Their approach integrates robotics and sensors, resulting in an advanced but high-cost solution. While this system enhances nutrient analysis efficiency, its cost may be prohibitive for small-scale farmers, a drawback that could be addressed by simplifying the hardware.

Rigor G. Regalado and Jennifer C. Dela Cruz explore a similar soil pH and nutrient analyser, combining colorimetric techniques with sensor data integration [3]. The strength of their work lies in its accurate multi-sensor approach, but like the work by Amrutha A., Lekha R., and Sreedevi this complexity may lead to higher implementation costs and require significant maintenance.

The pH mapping system developed by A. F. Kheiralla, Waddah Tilal El-Fatih contributes significantly to precision agriculture by providing real-time soil pH data [4]. However, it fails to consider other essential soil nutrients such as nitrogen or phosphorus, limiting its utility in comprehensive soil health analysis.

Finally, Tamal Adhikary, Amit Kumar Das, Md. Abdur Razzaque present a sensor-based system for real-time macronutrient (NPK) measurement [5], which excels in on-field performance. The limitation here, however, is that the system’s focus on specific nutrients may miss important data on other soil health factors like micro-nutrients or pH and Moisture.

Table 1: Literature Review of Papers Referred

S. No	Author’s Names	Title	Technique Used	Key Findings	Drawbacks
1.	Harshal M. Khairnar, Sangeeta S. Kulkarni.	Automated Soil Macro-Nutrient Analyzer using Embedded Systems.	Colorimetry with microcontroller for soil analysis.	Reduced human errors and time in NPK measurement.	Limited to macro-nutrient analysis; does not handle micro-nutrients.
2.	Amrutha A., Lekha R., A. Sreedevi.	Automatic Soil Nutrient Detection and Fertilizer Dispensary System.	Robotics-based nutrient detection system.	Automated nutrient analysis with dispensing capabilities.	High system cost due to multiple sensors and robotic components.
3.	Rigor G. Regalado, Jennifer C. Dela Cruz.	Soil pH and Nutrient (N, P, K) Analyzer using Colorimetry.	Colorimetry with sensor integration.	Accurate pH and nutrient analysis through colour sensor and pH sensor.	Increased system complexity with multiple sensors.
4.	A. F. Kheiralla, Waddah Tilal El-Fatih.	Design and Development of On-the-Go Soil pH Mapping System for Precision Agriculture.	Field pH mapping system integrated with sensors.	Provides real-time soil pH data for precision agriculture.	Focuses only on pH and ignores other essential nutrients.
5.	Tamal Adhikary, Amit Kumar Das, Md. Abdur Razzaque.	Test Implementation of a Sensor Device for Measuring Soil Macronutrients.	Sensor-based real-time NPK measurement.	Effective for on-field, real-time nutrient monitoring.	Limited to specific macro-nutrient types.

Table 1 Summarises the referred papers and their findings along with their drawbacks used for the study of our project these papers have helped us innovate the existing solutions for soil analysis. The reviewed papers offer valuable contributions to soil nutrient analysis, most of them are limited either by high costs due to complex systems or by their focus on only few essential nutrients. Our project, Soil Analyser with AI-based Crop and Fertiliser Recommendation System, addresses these limitations by providing a cost-effective, innovative nutrient analysis tool that uses AI for recommendations. This differentiation allows for real-time insights for farmers, improving both soil health management and crop yields.

Proposed Work

Feasibility

The Soil Analyser with AI-based Crop and Fertiliser Recommendation System, is based on the combination of existing, proven technologies and innovative AI integration. In our system there are sensors that accurately measure key soil parameters such as Nitrogen (N), Phosphorus (P), Potassium (K), pH, and Calcium etc. These sensors are readily available and can be sourced at low cost, making the hardware component of the project feasible from both a technical and economic standpoint. Microcontrollers like ESP32 and Arduino are widely used in embedded systems due to their low power consumption and versatility in handling real-time data acquisition and transmission.

In addition to hardware, the use of artificial intelligence (AI) using cloud-based platforms such as Google Cloud or AWS ensures that real-time data analysis can be achieved. The AI system will be trained on a large dataset of soil conditions and crop requirements, making it adaptable to different environments and farming needs. Cloud-based AI solutions have proven to be effective in various industries and are particularly well-suited to precision agriculture, where they can provide customised recommendations based on data.

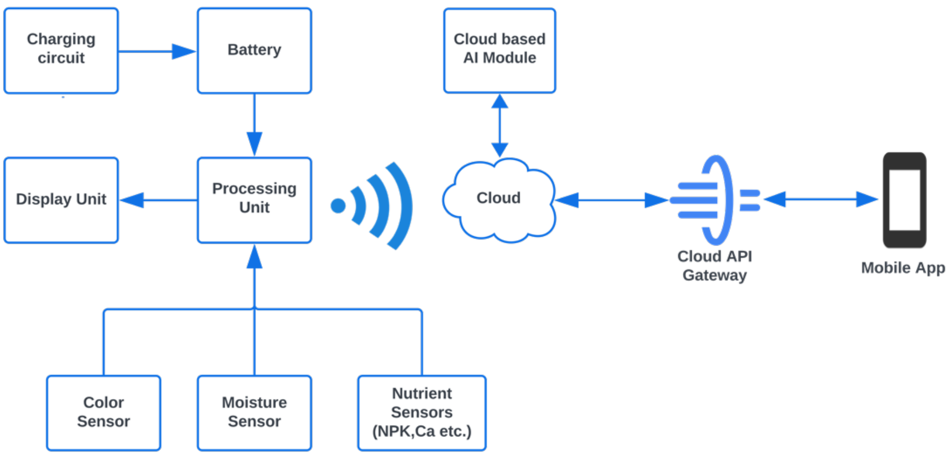

Fig. 1: Block Diagram

Detailed block diagram is shown in Fig. 1, It shows the functional flow of our project. The device consists of key components: soil sensors (NPK, pH, moisture, colour sensor etc.), a processing unit (ESP32/Arduino), a connectivity module (Wi-Fi/Built-in), and a cloud platform that contains the AI model. Once soil data is collected via the sensors, it is processed by the Processing unit and transmitted to the cloud. The AI analyses this data and generates crop and fertiliser recommendations, which are then sent to the user's mobile application via API Gateway. The system is designed to be portable and energy-efficient, making it suitable for use in both rural and remote farming areas.

Need for the Project

Agriculture is facing numerous modern challenges, including soil degradation, inefficient fertiliser use, and the increasing pressures of climate change. Traditional farming practices often rely on trial and error, leading to overuse or underuse of fertilisers, poor crop yields, and environmental harm. In regions where access to agricultural expertise is limited, small scale farmers struggle to maintain soil health and productivity. There is a clear need for a solution that provides accurate, real-time soil analysis and actionable recommendations, tailored to each farmer's specific soil conditions and crop requirements.

While lab-based soil testing is available, it is both time-consuming and costly, making it impractical for regular monitoring on small and mid-sized farms. Our project addresses this need by offering an affordable, easy-to-use system that delivers real-time nutrient analysis and AI-based recommendations directly to farmers via a mobile application. The use of real-time data helps farmers to make more informed decisions about fertiliser application and crop selection, reducing waste and improving soil health over time.

Overuse of chemical fertilisers contributes to soil degradation, pollution of water bodies, and greenhouse gas emissions. By providing accurate, tailored fertiliser recommendations, our project helps minimise environmental impacts. Our system is also designed to suggest alternative and organic fertilisers where appropriate, encouraging more sustainable farming practices. This aligns with global agricultural trends towards reducing environmental footprints and ensuring long-term soil viability.

Significance of the Project

Our project aims to make a significant impact on both agricultural productivity and environmental sustainability. For farmers, particularly in developing countries, access to affordable and reliable soil analysis tools can improve their ability to optimise crop yields and manage soil health effectively. By using AI in the system, we not only provide nutrient analysis but also provide suggestions related to the specific needs of each farmer. This reduces the guesswork involved in farming, leading to better resource management and improved economic outcomes.

The precision and efficiency offered by our project is enhanced by its ability to continuously learn and adapt because of AI. As more data is collected, the AI system becomes more accurate in its predictions, offering farmers increasingly precise recommendations. This also opens up the potential for long-term soil health monitoring, where farmers can track changes in soil composition over multiple growing seasons. The cloud-based infrastructure allows for easy scalability, meaning the system can be adapted for use across a wide range of farming scales, from small scale to larger commercial operations.

For environmental impact of agriculture, our project helps in reducing the harmful effects of over-fertilisation. Traditional fertiliser application methods often result in excess fertiliser being applied, which leads to nutrient runoff, polluting nearby water bodies, and contributing to soil degradation. By providing precise recommendations based on real-time soil data, our project ensures that only the necessary amount of fertiliser is applied, hence reducing these environmental risks. Moreover, the AI system's ability to recommend crop rotations and alternative fertilisers further supports sustainable farming practices.

Methodology

Flow Chart

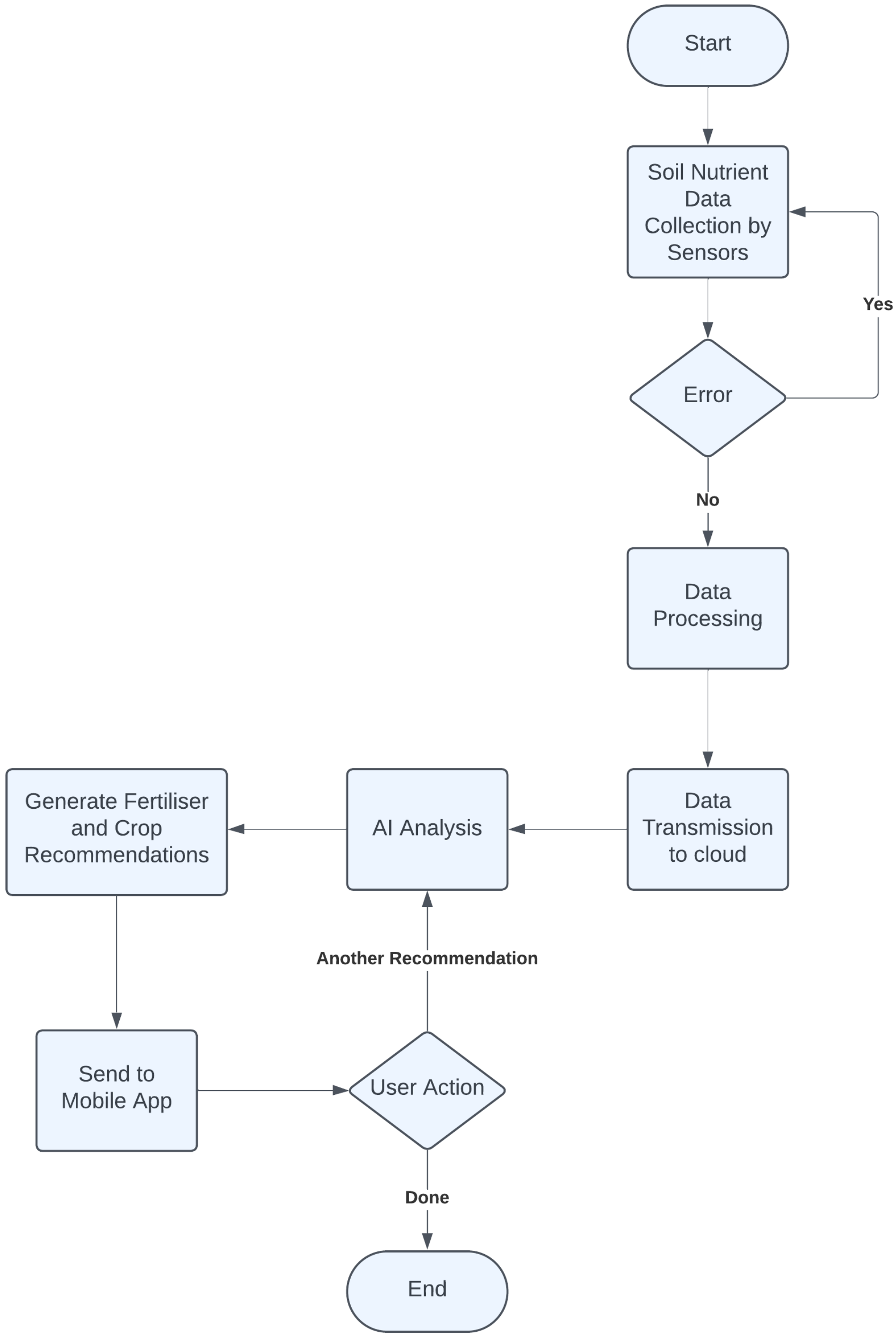

Fig. 2: Flow Chart

Fig. 2 represents the flow of operations in our project, the Soil Analyser with AI-based Crop and Fertiliser Recommendation System. The process begins with Soil Data Collection via Sensors, where various sensors gather key soil parameters such as Nitrogen (N), Phosphorus (P), Potassium (K), pH, and moisture levels. If any error is found the processes is repeated.

The collected data is then passed to the Processing Unit for Data Preprocessing, which involves converting the sensor data into a readable format. The Processing Unit filters and organises the data before sending it to the cloud for further analysis.

Once the data is pre-processed, it moves to the Cloud via the device's Wi-Fi connectivity in the Data Transmission stage. In the cloud, an AI-based algorithm processes the data. The AI Analysis step is where the system compares the soil data against an extensive database of soil and crop conditions. This analysis helps the system generate personalised recommendations for crop selection and fertiliser application.

After the AI has completed its analysis, the system moves to the Generate Crop & Fertiliser Recommendations phase. Here, specific recommendations are formulated based on the soil's nutrient levels, aiming to optimise crop yield while minimising fertiliser wastage.

Finally, the recommendations are sent to the user's mobile app in the Send Results to Mobile App stage. The User Action phase concludes the process, where farmers can apply the AI-driven suggestions to manage their crops and soil effectively or they may choose to get other suggestions from AI. This flow ensures that farmers receive data-driven insights directly from their soil conditions.

This flowchart outlines the entire data journey, from collection to recommendation delivery, ensuring efficient soil management and crop production.

Facilities Required

Hardware

1. Processing Unit (ESP32/Arduino Nano/Raspberry Pi Pico).
2. Sensors (NPK, Ca, Mg, pH, Moisture, Colour Sensor, etc.).
3. Power Supply (Li-ion Battery, Power Management IC & Charging Circuit).
4. Communication Module (Built-in/Wi-Fi/GSM/LoRa).
5. Display (TFT/OLED).

Software

1. IDE (Arduino IDE/PlatformIO).
2. Cloud Platform (AWS IOT/Google IOT/ThingsBoard).
3. AI Model (TensorFlow/PyTorch/Edge Impulse).
4. Application Development (React Native/Android Studio).
5. Data Processing Tools (Chart.js/Plotly).

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Sign

Siddharth Dilip Patil

Siddhesh Kamalakar Sutar

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Students **Guide**

Mr.R.R. Suryawanshi