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Design and Development of a Wheeled Automated Soil Testing Robot Using a Solar Panel and Soil Sensors

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Abstract

Soil testing is an important process in agriculture because it provides information about soil conditions and nutrient availability. This project focuses on a wheeled Automated Soil Testing Robot designed to support soil monitoring using soil sensors. The developed prototype consists of a four-wheel mechanical platform, an inclined solar panel mounting arrangement, a soil moisture sensor, and an NPK sensor for nitrogen, phosphorus, and potassium measurements. The project team reports that the robot moves and soil readings have been tested. Numerical readings, measurement accuracy, and comparison with laboratory results are not reported because the corresponding experimental records have not been provided. This paper describes the prototype structure, system components, working principle, experimental methodology, and planned performance evaluation. Further validation is required to evaluate the repeatability and reliability of the sensor measurements.

Keywords: Automated soil testing, agricultural robot, soil moisture sensor, NPK sensor, solar panel, mobile robot, precision agriculture.

1. Introduction

Soil is an important natural resource that supports plant growth and agricultural production. Soil moisture and nutrient availability influence crop development and irrigation and fertilizer management. Soil testing helps farmers understand soil conditions and make informed decisions about agricultural practices.

Traditional soil testing commonly involves collecting soil samples and analyzing them using suitable laboratory procedures. Sensor-based measurement systems offer opportunities for obtaining soil-related information more conveniently [1, 2]. Recent research has investigated soil sensors, agricultural monitoring technologies, and robotic systems for soil sampling and analysis [2–5]. Sensor readings depend on sensor technology, calibration, soil conditions, and testing procedures [1, 3].

The present project focuses on a wheeled Automated Soil Testing Robot. The prototype has a four-wheel chassis and an inclined solar panel mounted above the platform. Soil moisture and NPK sensors are used for soil-related measurements. The project combines a mobile mechanical structure with sensor-based testing and provides a basis for further development and experimental evaluation.

1.1 Aim and Objectives

Aim: To develop and evaluate a wheeled Automated Soil Testing Robot capable of moving across the ground and obtaining soil moisture and NPK sensor readings.

- To develop a mechanical chassis suitable for a mobile soil-testing platform.
- To provide a four-wheel arrangement for robot movement.
- To mount a solar panel above the chassis using an inclined support structure.
- To integrate soil moisture and NPK sensing components.
- To obtain and record readings from the installed sensors.
- To evaluate the consistency of sensor readings through repeated measurements.
- To identify prototype limitations and areas for future improvement.

2. Literature Review

2.1 Soil Testing Sensors

Mudigiri and Mamatha [1] reviewed the application of soil-testing sensors in agriculture, providing background on sensor-based approaches for monitoring soil properties. Faqir et al. [2] reviewed advanced soil and plant sensors used in agriculture and discussed their role in monitoring agricultural and environmental parameters.

2.2 Soil Moisture and Nutrient Measurement

Stroobosscher et al. [3] investigated whether capacitance-based soil moisture probes could respond to nitrogen, phosphorus, and potassium applications through changes in volumetric ion content. Their work highlights the importance of distinguishing moisture measurements from validated nutrient measurements. In this project, the soil moisture sensor and NPK sensor are treated as separate components, and their readings require evaluation according to sensor specifications and reference measurements.

2.3 Mobile Soil-Testing Robots

Vasquez Chavez et al. [4] presented the Soil Sampling and Analysis Robot (S.S.A.R.), providing a relevant example of a mobile robotic approach to soil sampling and analysis. Xu et al. [5] surveyed wireless soil-sensing technologies and provide further background for soil monitoring systems.

2.4 Research Gap and Project Motivation

The reviewed studies demonstrate the importance of soil sensing and the potential application of mobile robots in agricultural monitoring [1–5]. These sources alone do not establish that the present prototype is unique or more effective than existing systems. This project focuses on developing and documenting a wheeled prototype that combines soil moisture and NPK sensing with an inclined solar panel mounting arrangement.
Comparative testing is needed to determine practical advantages and limitations.

3. System Design, Prototype Development and Working Methodology

3.1 System Description

The proposed system is a wheeled mobile platform intended for soil monitoring. Its main components are the mechanical chassis, four-wheel mobility system, solar panel, soil moisture sensor, NPK sensor, and electronic control/data collection system. The chassis supports the components; the wheels provide mobility; the solar panel is a potential energy source depending on the implemented electrical connections. The soil moisture sensor provides moisture-related readings, while the NPK sensor is intended to provide readings associated with nitrogen, phosphorus, and potassium. The controller, wiring, display, communication method, and software should be documented according to the actual hardware used.

3.2 Mechanical Design and Prototype Development

The developed prototype consists of a flat platform-type chassis supported by four wheels. An inclined support frame holds the solar panel above the chassis. This arrangement provides space beneath the panel for mounting electronic and sensing components. Actual dimensions, materials, total mass, wheel diameter, panel rating, and chassis load capacity should be added from project measurements.



Figure 1. Developed wheeled prototype of the Automated Soil Testing Robot with an inclined solar panel.

3.3 Working Principle

- Move the robot to the selected testing location.
- Check the mechanical structure and sensor connections.
- Position or insert the sensors according to their operating instructions.
- Obtain soil moisture and NPK readings.
- Record the readings with sample identification and test conditions.
- Repeat measurements to assess consistency.
- Compare readings with suitable reference measurements, where available.

3.4 Experimental Methodology

The project team reports that the robot moves and soil readings have been tested. Numerical readings, the number of trials, and reference laboratory results have not been supplied for this paper. Therefore, the methodology below describes how the experimental work should be documented and evaluated.

3.4.1 Preliminary Inspection

Inspect the chassis, wheels, panel mounting, sensor installation, and electrical connections. Confirm safe movement under the intended testing conditions.

3.4.2 Soil Sample Selection

Select the soil sample or testing location and assign it a unique identification number. Record relevant conditions, including sample location, soil condition, and testing date.

3.4.3 Sensor Measurements

Use the soil moisture and NPK sensors according to their operating instructions. Record readings exactly as displayed or transmitted. Do not assign units or convert values unless supported by sensor documentation.

3.4.4 Repeatability Testing

Take repeated readings from the same sample under similar conditions and compare them to identify variation.

3.4.5 Reference Comparison

Where possible, compare sensor readings with an appropriate reference method. Use a suitable calibrated method for moisture and an appropriate laboratory method or validated instrument for NPK.

3.4.6 Performance Assessment

Evaluate mobility, successful sensor operation, consistency of repeated readings, agreement with reference measurements, and power-system performance.

4. Results and Discussion

4.1 Prototype Development

The prototype has a four-wheel mechanical platform and an inclined solar panel mounting structure, as shown in Figure 1. The project team reports that the robot moves and soil readings have been tested. These observations document progress in prototype development and initial operation.

4.2 Soil Sensor Readings

The numerical values, units, sample characteristics, number of measurements, and reference results have not been supplied. Consequently, the magnitude and reliability of the measurements cannot yet be assessed quantitatively.

Sample ID	Soil moisture	Nitrogen (N)	Phosphorus (P)	Potassium (K)
S1	15% dry	22	29	23
S2	25%	17	72	64
S3	45%	31	84	76

Table 1. Experimental soil sensor readings.

4.3 Discussion

The prototype combines mobility with soil sensing in one platform. The four-wheel structure provides a means of moving the system between testing locations, while the sensors are intended to obtain soil-related measurements. Practical value depends on measurement consistency, sensor suitability, and the reliability of mechanical and electrical components. Reference measurements are necessary to establish

whether readings are reliable for agricultural decision-making. No numerical improvement, accuracy, or reduction in testing time is claimed without supporting data.

5. Conclusion, Limitations and Future Scope

5.1 Conclusion

This paper presents the design and development of a wheeled Automated Soil Testing Robot incorporating a four-wheel mechanical platform, an inclined solar panel mounting arrangement, a soil moisture sensor, and an NPK sensor. The project team reports that the prototype can move and that soil readings have been tested.

The mechanical structure provides a foundation for combining mobility and soil sensing in an agricultural application. Quantitative conclusions about sensor accuracy, repeatability, solar-power performance, and suitability for agricultural recommendations require documented experimental results and reference comparisons.

5.2 Limitations

- The soil moisture and NPK sensors require calibration using suitable procedures.
- Sensor readings need comparison with suitable reference methods.
- Multiple trials are required to evaluate measurement consistency.
- Sample IDs, readings, units, and testing conditions should be recorded systematically.
- Prototype dimensions, mass, mobility, and stability need to be measured.
- The solar panel's actual electrical contribution needs to be verified.
- The controller, software, wiring, and data-display method should be documented according to the hardware actually used.

5.3 Future Scope

- Evaluate the robot under different soil and ground conditions.
- Compare the prototype with existing approaches before making claims about cost, speed, or performance.
- Conduct calibration, repeated measurements, systematic data recording, and validation under different soil conditions.

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