An Intelligent Crop Lifecycle Automation and Soil NPK Estimation System using TFLite and Sensor Fusion

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Abstract

The trend of pressure on the controlled crop farming and sustainable agriculture has led to the growing urgency of the search of the reliable indoor crop production and economical means of soil health analysis. Traditional indoor farming technologies tend to be based on manual control, fixed control measures, or costly laboratory-based soil analyzes, which is why they are inaccessible and inefficient in continuous terms. This paper introduces a multi-purpose smart indoor crop growing and on-field soil intelligence system that is aimed at offering automated environmental regulation, real-time monitoring, and low-cost soil nutrient estimation. To control temperature, humidity, and irrigation, the indoor cultivation unit is controlled by a deterministic, rule-based control structure that uses a four-stage crop life-cycle model to utilize real-time sensor feedback. The two- layered safety system allows quicker detection of anomalies and continued recording of data that will be used to tolerate faults. An on-field soil analysis module to aid cultivation decisions is indirectly estimated through low-cost sensors and smartphone-based imaging with lightweight and edge-deployable machine learning models to measure soil pH, type, and NPK. The system is completely offline and it does not rely on lab test or specialized NPK sensors. In experimental analysis, the system exhibits constant environmental control, consistent alerts, and correct inference of soil nutrients, which provides a low-cost and scalable solution to precise indoor agriculture and sustainable crop management.

Index Terms

Indirect NPK Estimation, Sensor Fusion, Edge AI, Soil NPK Prediction, Crop Life-Cycle Control, Serial Communication, Fault Tolerance, Real-Time Monitoring