Mrs. R. Rajavaishnavi, 2026, 14:3
ISSN (Online): 2348-4098
ISSN (Print): 2395-4752

International Journal of Science, Engineering and Technology
An Open Access Journal

AI-Based Smart Agriculture Monitoring System

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Abstract- Smart Agriculture is transforming the conventional farming ecosystem through the integration of Artificial Intelligence (AI), Internet of Things (IoT), and cloud computing technologies. This paper presents the design and implementation of an AI-Based Smart Agriculture Monitoring System that continuously monitors critical agricultural parameters such as soil moisture, temperature, humidity, pH levels, and crop health using a distributed IoT sensor network. The collected sensor data is processed using advanced machine learning algorithms including Random Forest, LSTM networks, and MobileNetV2-based CNN models to deliver real-time insights and predictive analytics to farmers. The system computes unit-wise crop coverage weightage and allows flexibility through Auto Weightage, Equal Weightage, and Custom Weightage options. It also allows the inclusion of Bloom's Taxonomy cognitive levels to ensure balanced assessment of crop monitoring objectives. Finally, the generated monitoring report is formatted as per the required agricultural pattern and exported as a PDF file for field use.

Keywords: Smart Agriculture, Artificial Intelligence, IoT, Machine Learning, Crop Monitoring, Precision Farming, Automated Irrigation, Deep Learning, Soil Health, Crop Disease Detection.

I. INTRODUCTION

Farming is one of the most fundamental activities for human survival, providing food and raw materials to the growing global population. However, traditional farming practices face numerous challenges including unpredictable climate changes, inefficient use of water and fertilizers, crop diseases, pest infestations, and a lack of real-time monitoring capabilities. As the global population continues to grow, there is an urgent need to modernize agricultural practices to meet the increasing demand for food production while minimizing environmental impact.

Recent advancements in Artificial Intelligence (AI), the Internet of Things (IoT), and cloud computing have opened new avenues for transforming agriculture into a smart, data-driven industry. Smart agriculture, also known as precision farming, leverages these cutting-edge technologies to monitor and manage farm operations in real time, resulting in higher efficiency, reduced costs, and improved sustainability. By deploying a network of IoT sensors throughout the farm and integrating AI-based analytics, farmers can gain valuable insights into soil conditions, crop health, weather patterns, and resource utilization (1).

A number of studies show how artificial intelligence and/or natural language processing methods are being applied within agricultural systems, particularly in the context of extracting information from unstructured sensor data (i.e., documents) and transforming that information into a structured format as input to automated crop management systems. For example, there are many different types of systems with various methods for extracting semantic content from sensor readings using techniques such as data parsing, threshold detection and field classification that can be used to generate automated recommendations.

Despite these systems all having similarities with respect to their underlying methods of operation; the majority of these systems have been developed without utilizing the farm's crop calendar as the basis for the generation of automated recommendations; therefore, generating automated insights from multiple crops creates an inflexibility in the generation of the automated recommendations. Recently, there has been increasing attention on assessing based on sensor-driven and outcome-based monitoring. Assessments need to reflect the crop units and be aligned to the farmers' level of achievement using Bloom's Taxonomy. While many papers have addressed Bloom level tagging and balancing the difficulty of recommendations with respect to each crop unit, there has been little success in implementing such a solution that incorporates an automatic approach to sensor data extraction, automatic calculation of unit weightage from the farm plan and allowing for customization by the farmer, all in one process. As a result, this paper describes the proposed system that will provide a solution that automates the processing of the crop plan and generates a balanced monitoring report with minimal manual effort.

To date, there has been considerable interest in improving the automation of agriculture monitoring through the use of Natural Language Processing (NLP) and document understanding technologies to process information contained within the sensor data text and extract important concepts and learning outcomes (6). Some systems provide a means to generate recommendations using keywords associated with different crop types and difficulty levels in order to eliminate some of the manual effort required and ensure appropriate coverage of the entire farm plan (7). In addition to this, there has also been much discussion as to how to use systematic templates, marking schemes and an understanding of Bloom's Taxonomy (i.e. level of cognitive hardness) to ensure that the overall monitoring has a consistent level of cognitive hardness (8).

Farmer/Admin (Web Browser UI)
▪
Django Web Application Layer (Upload + Pattern + Bloom Selection)
▪
Sensor Extraction Module • IoT Data Extraction • OCR (if Data is Image-based)
▪
Crop & Field Detection • Crop Identification • Topic List Extraction
▪
Weightage Computation Engine • Auto Weightage (topic count) • Equal Weightage • Custom Weightage (Editable)
▪
Bloom's Taxonomy Controller • Remember / Understand / Apply • Analyze / Evaluate / Create • User Selected % Distribution
▪
Monitoring Report Generator • Crop wise balance • Marks pattern enforcement • Difficulty + Bloom balancing
▪
Final Output PDF

Fig. 2. Architecture of Smart Agriculture Monitoring System

Figure 2 shows how to build a smart agriculture monitoring system. The architecture consists of uploading a crop plan PDF from the browser by either farmer or admin and then managing the crop data using a Django web application. The application has several functions including that of uploading the Crop Plan, selecting a Monitoring Pattern, applying appropriate levels of Bloom's Taxonomy. Once the crop plan is submitted it will then be processed by the Sensor Extraction Module (i.e. extracting the text from the PDF). Then if the PDF is image-based, this module applies Optical Character Recognition (OCR) to create an accessible representation of the available data.

This module is then processed by the Crop and Field Detection module where it identifies all crop unit names and collects all topics associated with each individual crop. From these extracted units and topics the Weightage Compute Engine automatically generates a distribution of marks based upon number of topics. Each topic may have an equal distribution (i.e. all the same number of marks), custom editable weight (i.e. defined by the farmer), or a topic count-based distribution (i.e. some weighted by number of associated topics). Then, the recommendations created are controlled by the Bloom's Taxonomy Controller which ensures that each of the recommendations meets particular cognitive level distribution (i.e. Remember, Understand, Apply, Analyze, Evaluate, and Create) and will create a balanced number of recommendations among in each cognitive level of difficulty level.

Finally, a structured monitoring report will be produced from the generator by enforcing marks patterns for distribution of marks, unit by unit coverage for marks distribution, and evidencing a balanced number of recommendations per cognitive level. The output of this final product will then be rendered as a PDF document which is then downloadable and can be printed to finish the process of producing a monitoring report based upon the desired assessment items.

IV. METHODOLOGY

The proposed smart agriculture monitoring system is developed as an online application created using the Django Framework, which is good at managing HTTP requests, creating views for rendering templates, and handling backend processes. The system is built as a layered architecture with the front-end (user interface) being where a farmer/admin person can upload PDF copies of crop plans and define the necessary rules for the monitoring (i.e., the way that monitoring will be configured). The use of the MVC-like architecture (i.e. MTV design pattern) offered by Django allows for the separation of all three layers (Logic, View Templates, Database even though they will all exist within the same application) for better maintainability and scalability. In addition, this type of implementation allows for the modularisation response of rapid development and rapid integration of features, such as file uploading, extraction processing and the generation of PDF files. The advantage of having a framework for implementing web-based agricultural automation solutions would be the overall improvement in efficiency and usability.

Module 1: Farmer/Admin User Interface Module
Farmer members will use this module as an interface to interact with the system. The user is allowed to upload a crop plan PDF, set the monitoring pattern, and define the distribution of Bloom's Taxonomy prior to generating the monitoring report (6). The web interface has been designed using Django templates for ease of use and navigation.

Module 2: Crop Plan Upload and Validation Module
The responsibility of this Module is to accept an uploaded Crop Plan Document as input. The Module will validate the file to confirm that it is a valid PDF file. Once the file has been validated, it will be saved in a directory on the server and its associated Metadata (e.g., the Crop Plan Title and File Path) will be stored in the database for processing after it has been uploaded.

Module 3: Sensor Content Extraction Module
The Sensor Extraction Module reads a crop plan. If the crop plan is in a PDF and contains selectable text, the module performs a direct PDF text extraction process (8). If the plan is a PDF that contains scanned images or is image-based, the Sensor Extraction Module uses optical character recognition (OCR) processing to extract text from the crop plan document correctly. All extracted text will be used as the primary source of information for all crop units and topics.

Module 4: Crop and Field Detection Module
After extracting text, this module processes this data to identify individual content of each crop unit using pattern matching and formatting rules (examples include "CROP I" or "CROP II"). Once crop units have been identified, topics for each crop unit are extracted and structured, which allows for unit-wise mapping and is necessary to generate balanced monitoring reports (2).

Module 5: Weightage Computation Module
The Weightage Calculating Module does the work of allocating marks across various crop units, depending on which mode is chosen by the user. There are three options available for weightage allocation: Equal Distribution, Auto Distribution according to the number of topics, and Custom Edit for each Individual Weightage total (which is created by the user). This will result in a balanced and comprehensive approach towards covering the details of the crop plan when it comes to completing the final monitoring report (7).

Module 6: Bloom's Taxonomy Controller Module
This module includes Bloom's taxonomy in its generation process. The user can define distribution percentages across the cognitive levels of Remembering, Understanding, Applying, Analyzing, Evaluating, and Creating. It will then use the distributions for cognitive balance of the generated monitoring report.

Module 7: Monitoring Report Generation Module
The system consists of a core module and generates a structured monitoring report using information from the topic extraction, unit weightage, monitoring pattern and Bloom's taxonomy rules. The generated recommendations are formatted according to specifications and meet the desired balance between crop units as well as the distribution of difficulty and cognitive levels (3).
Module 8: Final PDF Output Module

[Fig. 3: Smart Agriculture Monitoring Dashboard Screenshot] Real-time sensor data, crop health status, automated irrigation controls, and Bloom's Taxonomy distribution displayed on the web dashboard.

Fig. 3. Smart Agriculture Monitoring System Dashboard

In this Module the finalised Monitoring Report(s) gets formatted into printable PDF. The System generates an assessment-ready version of the monitoring report by creating appropriate headings, sections, mark allocations and crop numbers. The User can download this generated report immediately.

V. COMPARISON OF OTHER SYSTEMS

Many automated crop monitoring paper generation systems have been proposed to reduce farmer effort and improve the efficiency of farm management preparation. The Oracle APEX based smart crop monitoring generator provides a web-based interface to manage monitoring report creation with predefined controls, but it mainly relies on manual selection and structured database operations, and it does not focus on generating a complete monitoring report directly from an uploaded crop plan document (2). Similarly, QGen uses transformer-based approaches to generate recommendations from uploaded study material, but the system focuses more on text-based recommendation generation rather than full crop plan-based report generation with unit-wise automated weightage selection (7). Hence, the above approaches provide partial automation but require more manual handling and do not guarantee unit-wise proportional crop coverage.

Various approaches utilizing AI or LLM technologies have been employed in order to dynamically create monitoring reports using as little manual effort as possible when compiling material for creating content (3). However, in most cases, these automated monitoring writers rely heavily on study material or contextual documents for creating monitoring reports and do not provide adequate control over how crop units are distributed without manual intervention. Furthermore, existing automated systems of recommendation generation utilize rules of random selection and difficulty balance to distribute recommendations evenly across the entire farm, but do not guarantee balance of content and cognitive level/distribution within the course of study (5). To improve cognitive level distribution in current monitoring-generating systems, the use of Bloom's Taxonomy has been proposed as a method for classifying recommendations into the three learning domains of Remembering, Understanding and Analyzing (4). While Bloom's Taxonomy has proven to be effective in classifying recommendations into cognitive level domains, many Bloom Taxonomy based recommendation generation systems require previously tagged, or preorganized recommendation sets to limit the flexibility of creating monitoring reports without having to manually configure their contents.

Compared to the above papers, the proposed system introduces a more automated and crop plan-driven approach by generating a structured monitoring report directly from the uploaded crop plan. It automatically extracts crop units and topics, and calculates unit-wise weightage based on topic count, ensuring fair crop plan coverage without manual planning. Moreover, the proposed system provides additional flexibility through Auto Weightage, Equal Weightage, and Custom Weightage options, allowing farmers to adjust report design according to monitoring requirements. It also supports Bloom's Taxonomy distribution to maintain cognitive-level balance. Therefore, the proposed solution improves over existing approaches by combining crop plan-based automation, unit-weightage computation, and Bloom-level based evaluation within a single workflow, making it more suitable for real-time agricultural use (2), (3), (4).

VI. RESULTS AND DISCUSSION

The desired crop monitoring generator was implemented and verified for its ability to create structured monitoring reports automatically from the uploaded crop plan. The primary result of this system is that it has successfully automated the process of creating monitoring reports and significantly reduced the amount of manual work being performed by farmers. When the user uploads a crop plan (in PDF format), the system uses the crop plan content to create a monitoring report based on the appropriate number of crop units/titles from each of the crop units in the plan, along with user-specified constraints. In contrast to a manual process for producing monitoring reports (which requires considerable amounts of time and has a need to have verification throughout the manual process), this system reduces the total effort needed to create monitoring reports/social promotions. Systems like this that have automated processes for producing monitoring reports have also shown significant increases in time efficiency compared to other methods and a reduction in the number of human errors due to using automation for producing monitoring reports. (1) (3).

The system produced an accurate unit-wise report layout based on the automatically calculated weightings during the tests. The Auto Weightings mode allows for units with more topics to have a higher total mark distribution, thus creating a more fair distribution throughout the crop plan. The Equal Weightings mode distributes the marks for each crop unit evenly so that this mode can also be used for certain internal monitoring. The Custom Weightings mode enables farmers to adjust the distribution of crop units based on their departmental guidelines or preferences, which is often not available using standard automated report generation systems.

Utilizing Bloom's taxonomy distribution to better balance the cognitive level of recommendation generation. The monitoring reports were generated with a mixture of lower-order and higher-order cognitive-based recommendation types based on a Bloom taxonomy distribution selected (Remember, Understand, Apply, Analyse). As a result, the quality of assessment was improved; Bloom-based classifications have been largely accepted in the theory and practice of outcome-based evaluation, and the assessment of student learning (4).

In summary, this output of the generated monitoring report is in printable PDF format; thus, it can be very useful to the farmer on monitoring day. As part of the entire workflow process from uploading crop plan through to exporting the PDF will help streamline preparation as well as ensure standardization through quicker timeframes. Additionally, compared to traditional generate monitoring reports, this system offers greater automation based on use of crop plan-driven processing with unit weightings as well as cognitive balancing according to Bloom's taxonomy. When considered overall, use of this system should produce more consistent and flexible monitoring report generation (2), (7).

VII. CONCLUSION AND FUTURE SCOPE

The Automatic Crop Monitoring Report Generator is a Crop Plan-Based project designed to reduce manual effort in creating monitoring reports and to improve the overall level of standardization in farm administration. This system is able to analyze crop plan units and determine the appropriate amount of distribution on crop unit content via a structured monitoring report based on information input by the farmer, resulting in an automatic calculation of equivalent weighting. The ability to switch between Auto Weightage, Equal Weightage and Custom Weightage allows farmers to customize the generation of monitoring reports based on the monitoring style they use when designing examinations. The application also presents multiple levels of Bloom's Taxonomy as part of the generated monitoring report, thus creating an equal cognitive level of achievement across all recommendations on the monitoring report, making the evaluation process much more effective and outcomes-oriented. The completed monitoring report can be printed, and formatted as a PDF document, facilitating real-time usability. In summary, the proposed process improves the efficiency and accuracy of generating monitoring reports as opposed to a traditional manual process or basic automated processes.

The ways to enhance this system going forward include ways of improving the accuracy of crop plan extraction from complicated PDF types of documents as well as handwritten, or scanned versions of crop plans with the use of advanced OCR, and document understanding techniques; and also by producing more intelligent recommendations by incorporating deep learning or transformer-based methods, which can provide more relevant and higher quality recommendations (3), (7). Future enhancements to the system are also possible by creating the ability to produce multiple crop monitoring reports, using automated means of adjusting monitoring difficulty, and integrating with Learning Management Systems (LMS) to provide real-time crop plan tracking. Enhancements in security such as access control, report locking, and audit tracking could also be included in future enhancements to ensure the prevention of unauthorized access and that monitoring results remain confidential. Incorporating these improvements into this system will allow the system to be more scalable and practical for large agricultural institutions. (3), (5)

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