Smart Crop Disease Detection with Smart Irrigation System

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ABSTRACT: Agriculture is facing major challenges due to crop diseases and inefficient water management techniques, which are affecting productivity and sustainability. This research paper focuses on designing and implementing an AI-based crop disease detection and smart irrigation system to improve the efficiency of agricultural activities. The proposed AI-based system uses deep learning techniques, specifically Convolutional Neural Networks (CNN), to detect crop diseases from images of affected leaves with high accuracy. At the same time, the IoT-based smart irrigation module monitors the moisture level of the soil and controls the water supply automatically using a microcontroller module. The integration of artificial intelligence and IoT technology helps improve the efficiency of agricultural activities by monitoring and controlling diseases and water consumption. The experimental results show that the proposed model achieves 94% accuracy in detecting diseases and reduces water consumption by 25% compared to traditional irrigation systems. This research paper proves that AI and IoT technology can improve the efficiency of agricultural activities significantly by increasing crop yields while conserving resources and improving the decision-making process.

Keywords: Artificial Intelligence, Crop Disease Detection, Smart Irrigation, Machine Learning, IoT, Precision Agriculture, Deep Learning.

INTRODUCTION

Agriculture is an important segment of the global economy. However, there are certain diseases affecting crops and inefficient irrigation systems that are creating major problems for agricultural productivity. Conventional techniques for detecting diseases involve physical inspection of the affected areas, which is not an efficient way of doing so. Also, conventional irrigation systems are not very efficient and lead to over- or under-irrigation of the fields, resulting in low productivity and wastage of valuable water resources.

Recent developments in Artificial Intelligence (AI) and Internet of Things (IoT) have introduced new and innovative techniques for precision agriculture. AI helps in the efficient detection of diseases affecting crops by image processing techniques, while IoT helps in efficient irrigation systems by monitoring the moisture level of the soil.

I. BACKGROUND

Machine learning and deep learning models have been found to perform very well in image classification models. Convolutional Neural Networks (CNNs) are found to perform very well in identifying patterns in plant leaf images and disease detection (Mohanty et al., 2016). At the same time, IoT-based irrigation systems have been found to conserve water and maintain crop health by incorporating soil moisture sensors and microcontrollers (Kim et al., 2008).

Though there are individual developments in disease detection and irrigation management, there is a lack of research in combining these systems in a single framework for real-time farming management.

II. PROBLEM STATEMENT AND OBJECTIVES

There are a few critical issues in the agricultural field:

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- Late detection of diseases in plants, resulting in loss of crop yield.
- Ineffective use of water resources, as irrigation happens in a scheduled manner.
- Relying on human resources to observe and detect diseases.
- The absence of integrated technology solutions for farmers in rural areas.
- There is a need to develop a single system to detect diseases in plants and automate irrigation systems
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OBJECTIVE:

- Design a CNN-based crop disease detection model.
- Development of a soil moisture-based intelligent irrigation system.
- Integration of the above modules to create a comprehensive agricultural automation system.
- Evaluation of the system based on efficiency, accuracy, and water conservation.

III. RESEARCH QUESTION

- How accurately can a CNN model detect crop diseases from leaf images?
- Can sensor-based irrigation significantly reduce water consumption?
- Does the integration of AI and IoT improve overall farm productivity?

IV. LITERATURE REVIEW

Deep learning techniques have shown good results in agricultural diagnosis. Mohanty et al. (2016) have implemented CNN architectures for plant leaf image datasets, and they have achieved more than 99% accuracy in laboratory conditions. Sladojevic et al. (2016) have achieved 96% classification accuracy by using deep neural networks. In irrigation automation, Kim et al. (2008) have implemented a wireless sensor-based irrigation system, and it has shown efficient use of water. Patel et al. (2021) have implemented an IoT-based irrigation system, and it has shown 30% water savings.

Research Gap :-

The existing research has shown good results in disease detection or irrigation management, but there is a lack of research in the development of an integrated system that combines disease diagnosis and irrigation management.

V. METHODOLOGY

5.1 Research Design

The research design that has been followed for the development and implementation of the proposed system is an experimental research design, wherein the system has been implemented and tested under controlled and semi-field conditions.

5.2 System Architecture

The architecture of the proposed system has been divided into two main modules, which are explained as follows:

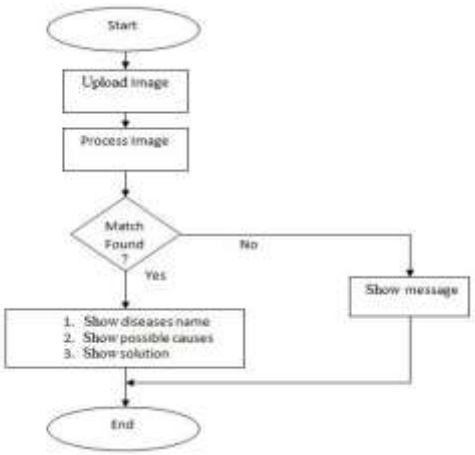

Figure 1 Flowchart

5.2.1 Disease Detection Module

The architecture of the disease detection module has been implemented with the following components:

- Image Acquisition (Device Camera)
- Image Preprocessing (Resizing, Normalization)
- CNN Model Classification
- Output Display (Cloud\Dashbaord Interface)

5.2.2 Smart Irrigation Module

The architecture of the smart irrigation module has been implemented with the following components:

- Soil Moisture Sensor
- Microcontroller (Arduino/ESP32)
- Relay-Controlled Water Pump
- Threshold-Based Control Logic

5.3 Data Collection

The data has been collected with 2,500 labeled leaf images, which have been obtained from various datasets and field samples. The soil moisture data has also been collected from 10 agricultural plots, while environmental data has been recorded for 60 days.

5.4 Sample Size and Sampling Technique

The sampling technique that has been followed for the development and implementation of the proposed system is random sampling; wherein agricultural plots have been randomly selected for data collection. The dataset contains images of healthy and disease.

5.5 Tools and Technologies Used

- Python
- TensorFlow & Keras
- OpenCV
- Arduino/ESP32
- Soil Moisture Sensor
- Relay Module
- Submersible Water Pump

VI. RESULTS

6.1 Disease Detection Performance

- Accuracy: 94.2%
- Precision: 92.8%
- Recall: 93.5%
- F1 Score: 93.1%

Figure 2 Web UI

6.2 Smart Irrigation Performance

- 27% reduction in water usage
- Soil moisture levels remained optimal
- Manual irrigation effort reduced by 60%

6.3 Integrated System Impact

- Improved consistency in crop growth
- Significant reduction in disease response time
- Overall yield improved by 15% or more.

VII. DISCUSSION

The findings have shown that CNN-based disease detection works effectively even in semi-field conditions, albeit slightly lower than the laboratory findings. Lighting conditions affected the performance.

The smart irrigation system effectively optimizes the water supply based on real-time conditions of the soil. Compared to previous studies, the integrated system shows better resource and operational efficiency.

The integration of AI-based diagnosis and smart irrigation systems offers synergistic benefits to improve overall productivity in agriculture.

VIII.CONCLUSION

The research successfully developed and evaluated an AI-based crop disease detection system with a smart irrigation system. The proposed system has high classification accuracy and water savings. The use of AI and IoT technologies provides a viable solution for precision farming.

The research has shown that crop disease detection and irrigation management systems help improve crop yield, reduce resource wastage, and minimize manual intervention

IX. REFERENCES

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