Smart Crop Management System with IoT and ML for Disease Detection, Soil, and Air Quality Monitoring

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Abstract

This paper presents a Smart Crop Management System that combines machine learning (ML) algorithms with Internet of Things (IoT) devices for all-encompassing agriculture management. The technology provides a unified method for disease detection, soil quality evaluation, and air quality monitoring by utilizing IoT devices for image capture, soil sensors, and air quality sensors. While soil sensors measure important parameters like moisture, pH, and nutrient levels, the captured images are used as input for machine learning models specifically designed for early disease detection. Environmental conditions are simultaneously monitored by air quality sensors. ML algorithms are used to process the integrated data and provide real-time insights into crop conditions. Proactive disease management, precision farming techniques, and a sophisticated comprehension of environmental factors affecting crops are made possible by this comprehensive analysis. Hence With the help of the Smart Crop Management System, farmers can now make more informed decisions to maximize crop health and yield while also taking a big step toward sustainable and data-driven agriculture.

Introduction

Crop cultivation and agriculture mainly depends on important ecological and environmental factors like air quality, water availability, soil condition etc. For letting a agricultural system to work at its full potential the farmers and agricultural experts must ensure proper quality checks of the crops for any phenotypical changes which may seem detrimental for the crop health, moreover routine checks of water availability and soil quality and air quality must be performed so that they can be sure that proper maintenance of cultivation land is maintained. Since all these tasks seem highly complicated to be done physically, taking in consideration the amount of time utilised for such a huge task, concepts of

Internet of Things (IoT) and Artificial Intelligence and Machine Learning (AIML) can be implemented to create devices to speed up the entire process using automation technologies. The base idea is to utilise IoT based sensors which will capture images of crops and monitor the physiological states of water and soil and air quality at periodic intervals and pass the data to a Machine Learning based model which will be programmed to classify the health state of the crops as well as predict whether the current air and water and soil quality is optimal for cultivation conditions or not. This idea will be extremely helpful towards farmers and agricultural experts as they will be able to keep track of real time data of their farms and save a lot of time for better utilisations.

Main concept

With the advent of modern technologies like Artificial Intelligence and Robotics ,the concepts of automation and advanced computations have become very simple and faster. Utilising these concepts and technologies it has become possible in recent times to develop various agricultural systems and automations which saves a huge amount of time and also enables in creating a integrated system which will perform routine checks to ensure the crop quality as well as other environmental conditions associated with it. For this project we will initiate our development processes in two phases , IoT phase and AI development phase. Both of these phases will constitute the respective concepts – developing various algorithms which will capture and read the data obtained from crops and discussed environmental factors and creating a custom automated prediction system which will predict whether the crop is in a healthy state or not. Moreover reading the real time data from air quality and soil the system will also be able to predict whether the present environmental conditions are suitable for cultivation or not.

1. IoT development phase : IoT refers to devices or sensor based technologies which are capable of transferring data across various machines or devices over internet systems. This phase of development will consist of utilising various sensors and microcontrollers to create a simple device which will collect image data of healthy and unhealthy crops and capture the real time data of air quality, soil conditions and moisture quality. This system will be developed using Raspberry Pi microcontroller board which is a pocket computer which is used to develop various IoT based devices. Further on utilising various

sensors more specifically camera modules (to capture images of crops) , moisture sensors (to monitor soil moisture quality) , air quality sensors (for monitoring air quality) and rainwater sensors , a full scope device can be developed which on completion will be able to accurately detect and collect data from the mentioned sources which will then be stored in a cloud server or database for passing it onto the next AI based model. The IoT based system will also be able to capture data on real time if one wants to utilise the data in the ML application at a given instant.

2. AI development phase : After collection and annotation of data from IoT pipeline, we will be developing a ML algorithm which will firstly read the images of healthy and unhealthy crops to create a classification algorithm which will categorise the images and new images into healthy crop and unhealthy crop. Using Python programming language and leveraging the backbone of neural networks using scikit learn and TensorFlow libraries, we will develop the classification algorithm as mentioned above. The reason of why we are using neural networks is because they use a highly computational network of mathematics and statistical methods to create equations and algorithms of the entire classification network. For the image processing part, we will be utilising Convolutional Neural Networks (CNN) which is a type of Neural Network which is specially designed for image processing as it computes images into numerical constants which are recognised by computers for algorithm creation. Using proper annotations and labels we will construct the model which will be accurately able to classify the dataset of images into healthy and unhealthy. After the model is finally created we will test the model accuracy by feeding it some unknown images or real time captured images which is presently absent in the dataset, if the model correctly predicts it then we will be ensured that our model is working correctly.

After the successful image processing model development, we need to process the data collected from air quality and soil moisture sensors. The idea behind this part is that we will be creating a dataset which will contain the sensor data along with manual annotated labels ranging between Positive environmental condition and Negative environmental condition. After creating the dataset, we will create a ML model which develops a prediction algorithm to predict between the mentioned categories. After model creation we will check for the accuracy by feeding it unknown data which may be collected real time from the IoT device. Successful accuracy check can conclude that the model is performing perfectly.

Given below is the diagrammatic representation of the project workflow

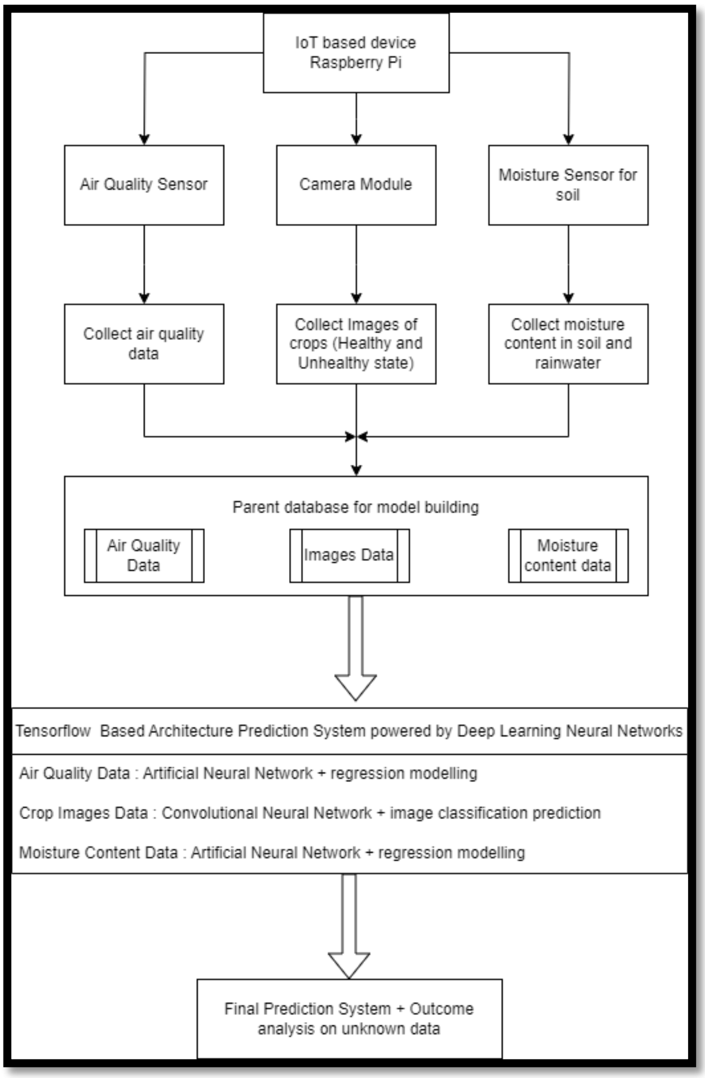

Fig 1. Diagrammatic representation of the project workflow

Conclusion and Future prospects

The integration of artificial intelligence and machine learning (AIML) and Internet of Things (IoT) technologies in smart crop management has started a revolution in agriculture that will have a major impact and open up exciting opportunities in the future. The efficiency and resource optimization of agriculture will be directly impacted by the introduction of Internet of Things (IoT) devices that are fitted with sensors to collect data in real time on crop conditions, air quality, and soil health. Farmers now have access to timely and accurate information, which greatly improves precision agriculture by enabling targeted interventions that maximize yields while minimizing resource waste. The ability of the machine learning model to categorize crop health based on photos helps detect diseases early, enabling farmers to take preventative action and reduce financial losses. Additionally, the system promotes sustainable farming practices by evaluating soil conditions and air quality in real-time and helping to optimize resource usage. Farmers are able to concentrate on making strategic decisions and managing their farms holistically because the time and labor associated with manual inspections are greatly reduced by the automation of routine checks through IoT devices.

Future prospects for this integrated system appear bright. More complex predictive models that offer insights into ideal planting times, climate patterns, and enhanced disease anticipation are expected to result from ongoing advancements in AIML technologies. Another possible approach that could allow automated interventions in different areas of crop management is the combination of IoT and AIML with robotics. The widespread use of IoT devices may help build a global agricultural network that will enable farmers all over the world to share information and exchange data in real time. Furthermore, as ongoing observation and adjustment to shifting environmental conditions become more and more important, the system's capacity to strengthen agriculture's resistance to climate change is an important future prospect. As the data produced by intelligent crop management systems grows, it can provide researchers and policymakers with information that will help them create sustainable agricultural policies that will help solve global issues pertaining to environmental preservation and food security. As a result, the application of IoT and AIML to agriculture is having revolutionary effects today, and the future of farming practices appears to be both technologically advanced and ecologically conscious.

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References

1. P. M. Jacob and P. Mani, "A Reference Model for Testing Internet of Things based Applications," Journal of Engineering, Science and Technology (JESTEC, vol. 13, no. 8, pp. 2504-2519, 2018
2. P. M. Jacob and P. Mani, "Software Architecture Pattern Selection Model for In ternet of Things based systems," IET Software, vol. 12, no. 5, pp. 390-396, October 2018.
3. H. Durmuş, E. O. Günes and M. Kırcı, "Disease detection on the leaves of the tomato plants by using deep learning," in 2017 6th International Conference on Agro-Geoinformatics, Fairfax, VA,, 2017.
4. M. Islam, A. Dinh, K. Wahid and P. Bhowmik, "Detection of potato diseases using image segmentation and multiclass support vector machine," in 2017 IEEE 30th Canadian Conference on Electrical and Computer Engineering (CCECE), Windsor, ON, 2017.
5. A. Demir, "Remote Monitoring of the Soil Quality with the Internet of Things," ECE Senior Capstone Project, 2017.
6. M. Islam, A. Dinh, K. Wahid and P. Bhowmik, "Detection of potato diseases using image segmentation and multiclass support vector machine," in 2017 IEEE 30th Canadian Conference on Electrical and Computer Engineering (CCECE), Windsor, ON, 2017.
7. J. Shirahatti, R. Patil and P. Akulwar, "A Survey Paper on Plant Disease Identification Using Machine Learning Approach," in 2018 3rd International Conference on Communication and Electronics Systems (ICCES), Coimbatore, India, 2018
8. P. Sharma, Y. P. S. Berwal and W. Ghai, ""KrishiMitr (Farmer's Friend): Using Machine Learning to Identify Diseases in Plants," in 2018 IEEE International Conference on Internet of Things and Intelligence System (IOTAIS), Bali, 2018.