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A Comprehensive Multi-Modal Framework for Plant Health Monitoring

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Abstract: Plant health monitoring has been a significant field of research since a very long time. The scope of this research work conducted lies in the vast domain of plant pathology with its applications extending in the field of agriculture production monitoring to forest health monitoring. It deals with the data collection techniques based on IOT, pre-processing and post-processing of Image dataset and identification of disease using deep learning model. Therefore, providing a multi-modal end-to-end approach for plant health monitoring. This paper reviews the various methods used for monitoring plant health remotely in a non-invasive manner. An end-to-end low cost framework has been proposed for monitoring plant health by using IOT based data collection methods and cloud computing for a single-point-of-contact for the data storage and processing. The cloud agent gateway connects the devices and collects the data from sensors to ensure a single source of truth. Further, the deep learning computational infrastructure provided by the public cloud infrastructure is exploited to train the image dataset and derive the plant health status
Keywords: Cloud Computing, Deep Learning, Internet of Things, Plant Pathology, Precision Agriculture, Transfer Learning.

I. INTRODUCTION

Plant health monitoring is a multidisciplinary field consisting of Plant pathology, Remote sensing, Internet of things, Machine Learning, and Image Processing. Plant pathology is the science that examines the causes of plant diseases, the ways in which diseases grow on individual plants, and the ways and means in which plant diseases can be controlled using advanced scientific technologies. It learns about diseases caused by environmental conditions. The introduction of tangible, highly effective, and inexpensive methods to detect and monitor plant and insect diseases in large areas can greatly help plant protection. In general, satellite imagery has been used as a primary source of information for accurate crop analysis in agriculture. However, procuring the latest satellite imagery is a very expensive and time intensive process, and data processing is also broad and complex. In addition to this, images obtained from satellites have low resolution and are only suitable for large subjects. This reduces their effectiveness in specific agricultural-based studies. Therefore, IOT-based technologies are starting to take the ground and make an impact, especially in the agriculture segment. Various sensors are employed to design a multi-modal approach for plant health monitoring. Image processing and augmentation techniques are used on the image samples to train the model accurately. Machine learning models and in-depth transfer learning are used to predict and differentiate plant diseases by examining image samples.

This paper describes the success of advanced research in terms of sensor technology, computing resources, and monitoring algorithms used to monitor plant health and provide a low-cost framework for plant health monitoring.

II. LITERATURE SURVEY

Developments in the field of plant health monitoring and plant pathology using autonomous techniques goes a couple of decades back. Earlier the concepts of remote sensing techniques were more popular and hence the majority of literature study available is based on the plant health monitoring and crop protection using remote sensing techniques [1]. Historically, remote sensing has been the primary tool used to diagnose plant health, especially for forest and rangeland management [2] and for crop yield prediction [3] [4]. Many non-destructive and non-invasive methods to detect and assess plant diseases cost-effectively have been studied, even though to date there is not significant research carried out on non-destructive methods. As a supplement to conventional methods, these new methods have great potential to facilitate and increase accuracy and precision in plant pathological research [5]. It describes the methods and their possibilities and also emphasizes the biological prerequisites and restrictions for practical applications. Disease monitoring and the introduction of more efficient and less expensive methods of detecting plant diseases in large areas can greatly help plant protection. In this regard, a variety of remote sensing systems have been introduced to detect and monitor plant diseases in a number of ways. [6]. Various monitoring techniques such as visual spectroscopy, infrared, fluorescence imaging, multispectral and hyperspectral imaging, thermography, magnetic resonance spectroscopy etc. have been studied in [7].

Based on these principles a satellite-based crop health monitoring system has been implemented for farmers [8]. Precision Agriculture or Precision Farming is a controlled farming technique which uses computer-based technology to ensure profitability, efficiency, and sustainability while protecting the environment and making informed decisions [9]. A never-before-seen access to high-resolution satellite images promoted the use of remote sensing in precision agriculture applications including the monitoring of crops, irrigation management, nutrient application, and disease and pest management.
However, very recently, deep learning and artificial intelligence has influenced plant pathological studies due to advancements in the access to cheap computational power and development of the field [10]. With the use of ML and AI, identification and classification of diseases has become a lot easier and more precise. [11] Proposes an end-to-end approach for the monitoring of crop health, and fitness, with the help of the internet of things, machine learning and drone technology to provide cost-effective plant health monitoring. [12] Outlines the state-of-the-art research of sensing technologies, feature extraction, and monitoring algorithms.
More techniques have been added to precision agriculture, very recently. Plant phenotyping is an emerging field of research and will continue to play an important role in the understanding of crop-related traits [13]. Understanding these features is crucial in order to be able to run an effective plant disease control [14]. Deep learning has shown a promising approach for fine-grained disease severity classification for smart agriculture as it avoids the labour-intensive feature engineering and segmentation-based threshold. Densely Connected Convolutional Networks (DenseNet) based transfer learning method to detect the plant diseases has been reviewed in [15], which expects to run on edge servers with augmented computing resources.
Transfer learning-based solutions for the detection of different diseases with the help of a simple image of healthy and diseased plants has been studied. DenseNet-121, a deep convolutional neural network model has been used for the detection of apple leaf diseases with an accuracy of more than 93% [16]. A multi-class classification problem is addressed in [17], in which the models were trained, validated and tested with the help of the 11, 333 and images in 10 classes. Current limitations and shortcomings of the existing system for the detection of disease models are discussed in [18], which is designed to help in the delivery of a decision support system for plant monitoring.

III.PROPOSED FRAMEWORK

This study proposes a multi-modal framework for plant health monitoring by integrating IOT and cloud-based deep learning technologies to demonstrate a low cost model for predicting plant diseases and health monitoring. The proposed framework is shown in Fig. 1. It abstracts the technological challenges by representing the entire architecture as a functional block diagram. The entire framework is represented by three functionally independent blocks. The first block is the hardware layer, which consists of all the sensors and on-board computers which collect the raw data from the plants. The second block is the networking block, which consists of the design of communication protocol for on-ground components and cloud integration. It helps in establishing a gateway service to connect to a cloud. The third block is the cloud layer, which uses the data collected to monitor the plant health and predict diseases with the help of cloud-based deep learning solutions.

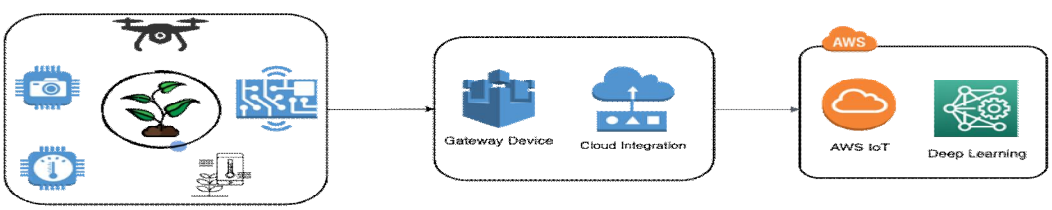

Fig.1 Architecture of Plant Health Monitoring System

1) *Block-1:* The first functional block in the figure shows the use of IOT sensors and devices to collect the data from the agricultural farms using camera modules (e.g. RPi camera modules), temperature and humidity sensors (e.g. DHT11). Drones can also be used to provide an aerial view of the site and establish health maps.
2) *Block-2*: This block shows the communication protocol used. The data can be wirelessly sent to a master microcontroller device using an RF communication module (e.g. LoRA module). The on-board computer could have a master-slave configuration. The master computer will be connected to an agent gateway such as AWS IOT, which provides an interface between IOT devices and cloud services. The slave devices can send the raw data collected to the master controller. MQTT is the most used publish-subscribe network protocol that transports messages between devices. The protocol runs over TCP/IP; however, any network protocol that provides ordered, lossless, bi-directional connections can support MQTT. It is designed for connections with remote locations where a small code footprint is required, or the network bandwidth is limited.

3) *Block-3:* The third functional block shows the cloud implementation. AWS IOT manages device communication through a message broker. Devices and clients can publish messages (raw data stream) to the message broker and also subscribe to messages that the message broker publishes. The proposed framework suggests the computational power of cloud resources such as AWS Sagemaker or GCP Datalab for post processing of data and using deep learning approaches for predicting plant health. With the help of cloud computing, the upfront cost of infrastructure and its maintenance can be avoided.

IV. CONCLUSIONS

Plant health monitoring is a multidisciplinary field comprising plant pathology, remote sensing and artificial intelligence. With the advancements in the field of deep learning and image processing in a cloud-native environment, the plant health monitoring systems have moved from remote sensing based technologies to deep learning based systems. This paper aims to provide a simplified low-cost framework for plant health monitoring using IOT, Deep Learning and Artificial Intelligence. Plant health monitoring systems have huge applications in crop yield prediction, health monitoring and forest rangeland management.

V. ACKNOWLEDGMENT

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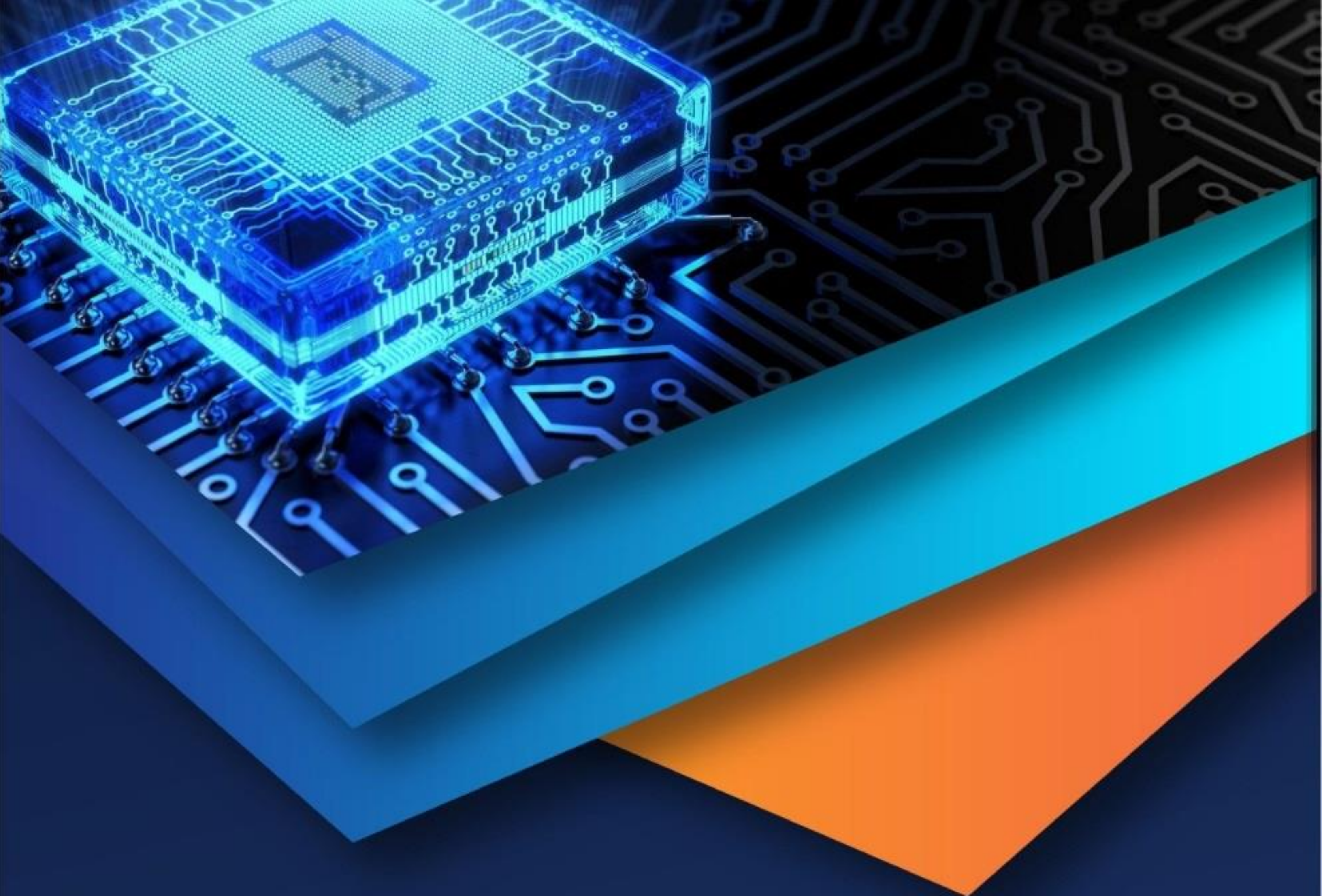

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