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A Review Paper on Crop Disease Detection for Smart Agriculture using AI and ML

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ABSTRACT

It is imperative that any plant disease be detected at an early age since any disease that might affect the plant may lead to loss of yields and, consequently, the loss of crops. Early detection not only prevents any losses but also saves the farmers time in carrying out unnecessary activities such as labour and other forms of activities. One of the techniques employed in modern intelligent agriculture includes the use of artificial intelligence in the detection of plant disease using photographs. It is done by taking a photograph of the plant using either a digital camera or a phone. Upon analysing the photograph, the computer makes the determination of whether the plant is diseased or not. This method can be used to detect any plant disease ranging from tomatoes, potatoes, and cotton to many other kinds of crops. Not only does it detect the disease, but it also gives advice on how to treat the plant in case of any disease using organic techniques, fertilisers, cultivation practices and also prediction of any disease likely to occur in the future due to climatic factors like temperature and humidity. Apart from all the above facilities, the system also provides facilities to predict future outbreaks of diseases based on environmental conditions such as humidity and temperature. Apart from this, the system also provides facilities such as disease diagnosis through cameras in real time and also an interface in the languages spoken by the farmers, such as Marathi and Hindi.

Keywords: *Crop Disease Detection, Smart Agriculture, Artificial Intelligence, Machine Learning, Image Processing, Multi-Crop Detection, Weather Prediction, Real-Time Detection, Mobile Camera, Regional Language Interface, Sustainable Agriculture.*

Introduction

Nowadays, smart agriculture is considered an important technological solution for enhancing crop productivity and minimizing losses during farming owing to the utilization of various technologies. The recent innovations in artificial intelligence, machine learning, deep learning, internet of things, image processing techniques have led to significant improvements in plant disease detection, crop monitoring, and fertilizers' recommendation. The authors developed a smart farming system for early detection of plant diseases through the analysis of leaf images and provided suggestions on disease treatment along with the forecast of weather. This approach helped to increase crop production, minimize losses, and made farming more convenient and effective for farmers [1]. Moreover, another article reviewed the current technologies which are used for crop disease detection through image processing technologies.

The authors provided a comprehensive discussion on the use of smartphones, drones, UAV, satellites, and different kinds of sensors for crop monitoring and disease detection. They emphasized the role of climate data, soil and other environment factors [2]. In addition, various approaches are used nowadays for the development of smart fertilizer recommendation and crop disease detection systems. The authors discuss the role of vision transformers and IoT-based smart farming technologies for the improvement of agricultural productivity [3]. There was also another farming approach that combined crop prediction, fertilizer management, and plant disease detection through a unified system. With the help of sophisticated models like ResNet-9, this system makes important recommendations for farmers about crop selection, fertilizer management, and plant disease detection. The ultimate aim of this approach is increasing agricultural efficiency, reducing crop loss, and promoting sustainable farming practices [4]. Furthermore, there was one more approach to identifying fruit diseases through a hybrid deep learning model. This approach involves multiple deep learning models along with feature fusion and decision fusion techniques. Some deep learning models include ResNet-50, VGG-19, and EfficientNet-B4. Such an innovative farming model promotes precision agriculture and crop disease identification [5]. There is yet another smart farming model that continuously monitors soil conditions and the environment with the help of IoT technology and other cloud-based platforms. Real-time monitoring data is used to manage irrigation and fertilizers effectively. Such a model can significantly help farmers with increasing crop growth while saving resources [6]. Climate change is now a big worry for agriculture and food security around the world. When investigating wheat cultivation, scientists found that alterations in climate might lead to variations in crop production, resulting in low agricultural productivity in many places. This study stressed the requirement for using new technologies and methods in agriculture to minimize risks associated with the climate [7]. According to the studies covered by the paper, it is evident that the current approaches in the area are largely concentrated either on plant disease detection, fertilizers recommendation, crop monitoring, or environmental analysis separately. Nevertheless, there is a need to develop integrated yet affordable and user-friendly AI-powered smart agriculture technologies that would assist in solving all these issues at once.

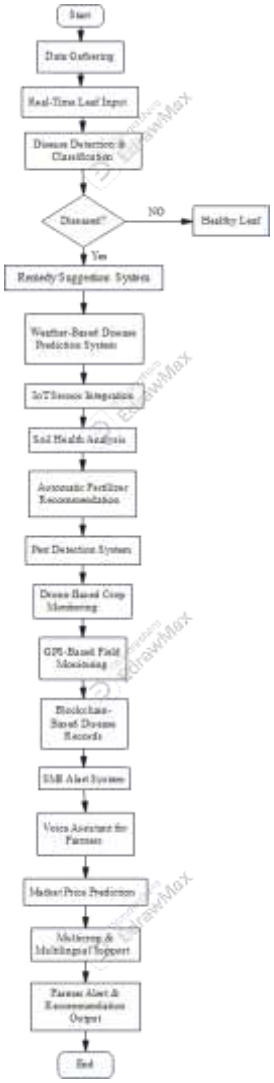
As for the discussed in the paper AI-powered smart agriculture approach, it appears to address the issue of modern challenges to agriculture through the creation of practical tools. Contrary to the previous methods used in agriculture, this approach does not concentrate solely on detecting plant diseases, but also predicting those, which may occur depending on the weather and climatic factors. The system offers treatment options together with organic treatment ideas that can result in reduced reliance on chemicals and make the farming process more eco-friendly. Furthermore, the system is equipped with a live weather prediction and warning system that allows farmers to be aware of the changes occurring in their environment and make decisions pertaining to farming and irrigation in a timely manner. IoT technology-based smart farming is another feature of the proposed solution that will assist farmers in increasing their productivity through better resource management. The system uses Marathi and Hindi languages to ensure that local farmers can easily access the platform without any trouble despite the lack of technical proficiency. Therefore, with all of its features, the proposed system aims at enhancing crop productivity while reducing losses associated with farming activities.

Proposed Methodology

The model suggested for this paper is aimed at presenting a smart solution for the detection and diagnosis of crop diseases through artificial intelligence, machine learning, and image processing. The use of smartphones or any other camera enabled device will enable farmers to detect whether their crops have any signs of diseases, making it possible to detect the state of the crop plant in order to determine its health condition. The key aim of this solution is to increase the productivity of farms, and minimize the risk of losing crops due to any unforeseen circumstances. The solution will help farmers to diagnose crop diseases at an early stage while also suggesting proper medication along with natural solutions to ensure that no excess chemicals are used. Moreover, the proposed solution will be able to predict possible diseases in the future based on environmental parameters such as temperature, humidity, and climatic factors. Additionally, the model will also include live weather forecast which will help farmers prepare for any unfavorable weather conditions and protect their crops against any adverse effects. Moreover, the suggested solution facilitates the IoT-driven concept of smart agriculture by utilizing sensors for the monitoring of various environmental parameters such as moisture, temperature, and humidity within the soil. The improvement in resource management and decision-making capabilities is guaranteed. Language support is provided in the form of Marathi and Hindi with an easy-to-use interface to facilitate

the involvement of local farmers without any technical background. Ultimately, the objective of this system is to increase the crop yield, save time and efforts, reduce farming losses, and adopt smart farming techniques.

The proposed system will be a smart plant disease detection system which involves the use of Artificial Intelligence (AI), Machine Learning (ML), and Image Processing. The system involves leaf images collected from the farmers either from their cameras or from the database, which also include other environmental factors like temperature, humidity, etc. Image resizing, cleaning, and preprocessing take place to increase the efficiency of the model. CNN can be implemented to carry out real-time disease detection and classification. Different kinds of diseases like Early Blight, Leaf Spot, Rust Disease, and Powdery Mildew can be detected through the use of mobile camera devices. After the detection of any particular disease, recommendations will be made on how to treat such disease involving medicines and fertilizers, and other necessary preventive measures which need to be taken to save the crops. Furthermore, predictions can also be made about the disease that might arise in the future according to the weather condition at the moment and sending early alerts to farmers against such disease.



Real-Time Crop Disease Detection and Monitoring System

Review of AI and MI Techniques in Crop Disease Detection Systems

The AI and ML technologies serve a significant part in current crop disease detection systems. Several research articles concentrate on the application of sophisticated AI techniques aimed at increasing the accuracy, speed, and efficiency of identifying diseases in plants. Such techniques enable early detection of diseases, prevent crop losses, and contribute to increased agricultural output. The following AI and ML technologies find applications in crop disease detection systems.

- **Computer Vision:** Computer Vision technology serves a popular means of crop disease detection because of its ability to analyze images of the plant's leaf in order to identify symptoms of diseases. The computer vision system makes it possible to detect signs of disease automatically through image analysis.
- **Deep Learning:** Deep learning stands for an advanced subset of AI techniques that prove to be highly efficient in the case of image-based plant diseases detection. The key advantage of deep learning technologies lies in their ability to detect key features of the plant images automatically. According to several research works, deep learning techniques enable accurate identification of crop diseases.
- **Convolutional Neural Network (CNN):** CNN is among the most popular deep learning techniques that are employed to detect diseases in crops. The CNN models have the ability to extract useful visual information like texture, colors, shapes, and diseases from the leaf images. This technique plays a significant role in classifying healthy and diseased crops.
- **AI for Weather Forecasting:** In today's world, there are many crop disease detection systems that use AI along with weather forecasting methods. The environmental variables like temperature, humidity, and rainfall are considered to forecast the occurrence of any diseases that can affect the crops. In this way, it becomes easier for farmers to avoid the outbreak of diseases through smart farming techniques.
- **Image Processing:** There are Image Processing techniques involved during the preprocesses step of crop disease detection systems. Techniques of image resizing, normalization, filtering, segmentation, and enhancement are some common processes used in this context. These processes help in increasing efficiency and effectiveness.
- **Disease Detecting in Crops Using Mobile Devices:** Another area receiving significant attention is that of designing mobile-based disease detection systems for crops since smartphones are easily accessible to farmers. In mobile-based disease detection systems, the farmers take pictures of the leaves, and artificial intelligence processes the pictures to identify any disease. Mobile-based systems have been found to be affordable, portable, and highly beneficial to rural farmers.
- **Disease Detection Using Drone Technology:** Drone technology is becoming common practice in modern agricultural research in relation to crop monitoring. The drones capture images from the crop field, which are then analyzed using artificial intelligence algorithms in order to detect diseases, pest invasions, and diseased portions of crops. This technology makes it possible for the farmers to monitor their large farms effectively.
- **Multilingual and Farmers Assistance Features:** Many of the new-generation crop disease detection software comes with multilingual and farmers' assistance features that generate alerts and provide disease information in local languages. There are also voice assistant features incorporated in these systems that send messages through SMS alerts. Thus, it can be stated that machine learning algorithms have revolutionized crop disease detection systems by making them more accurate, faster, and easy for farmers to understand and operate. Modern day researchers mainly concentrate on the use of deep learning algorithms, Internet of things, weather forecast tools, and smartphone-based apps.

Proposed Novel Features and Future Research Directions in Ai-Based Crop Disease Detection Systems

- **AI Disease Detection Before Symptoms Appear:** The intended system focuses on predicting plant diseases in crops based on signs before they start developing on the plant's leaves. While traditional methods of detecting crop diseases focus on identifying the diseases after their signs become evident, the intended system relies on factors like temperature, humidity, moisture content of soil, and changes in the amount of chlorophyll and thermal conditions of plant leaves for predicting crop diseases in an earlier stage.
- **Explainable AI (XAI) for Farmers:** Incorporation of explainable artificial intelligence technology in the proposed study will help address transparency issues along with ensuring interpretation of the results. Rather than giving only the prediction outcomes about the existence of diseases, it will help determine the areas of leaves that have been impacted and the reasons behind their being infected. Visualization methods, such as heat maps, attention-based deep learning, and explainable convolutional neural networks could prove helpful in making the decisions more interpretable by farmers who lack technological knowledge.
- **Offline Edge AI-Based Disease Detection System for Rural Areas:** The suggested study revolves around designing an offline AI-based crop disease detection solution that will cater to the needs of farmers in rural and remote locations where there is limited access to internet connectivity. Through the application of Edge AI, TinyML,Tensorflow Lite, and lightweight CNNs, the offline AI solution will be able to perform image analysis of plant leaves using the smartphone camera itself without the need for cloud server interaction. This method promises to minimize delays, ensure data security, reduce expenses, and enable farmers in poorly connected areas with timely disease detection.
- **Voice-Based AI Assistant in Regional Languages:** The proposed study will also focus on developing a multilingual voice-based assistance system which will assist in making the tool accessible to farmers with different language capabilities. Regional languages like Marathi, Hindi, Tamil, and Telugu can be supported using this system through speech recognition and text-to-speech capability. Voice inputs can be provided by the users to obtain information related to diseases, preventative techniques, and treatments in their native language.
- **AI and Drone Swarm-Based Smart Crop Monitoring:** The suggested approach involves the use of the latest drone swarm technology with AI capabilities for monitoring the crops and detecting diseases. In contrast to the current methods that involve the use of a single drone, the suggested solution makes use of multiple intelligent drones that operate together to increase monitoring efficiency, speed, and accuracy. Equipped with the imaging cameras and AI algorithms for image processing, the drones will be able to obtain and analyze images of the crops and detect the affected parts. This technology will be capable of producing GPS maps of disease distribution, mark affected areas, monitor the spread of diseases, and apply precise pesticide sprays to fight diseases. The use of modern technologies such as Swarm Intelligence, Reinforcement Learning, and Autonomous Navigation may facilitate efficient cooperation between drones, minimize the time required for monitoring and make decisions. The use of drones in combination with the latest AI technologies constitutes a cutting-edge research direction in smart agriculture that has yet to be explored.
- **Blockchain-Based Crop Disease Records:** According to the literature study conducted for the research, the use of blockchain technology for securing transparent and unalterable records of crop diseases, the use of pesticides, and other details regarding treatment is suggested. Agricultural applications involving the use of blockchain technology can ensure improved data security as well as facilitate any government-led verification processes regarding agricultural subsidies.
- **IoT and Smart Agriculture Integration:** The proposed research project also involves the use of IoT technology along with AI-based disease prediction in crops to develop a framework for smart agricultural monitoring. The IoT-enabled sensors placed throughout the fields can help in monitoring the various environmental and soil-related factors such as soil moisture,

temperature, humidity, rainfall, light intensity, and other atmospheric conditions. This live data can then be combined with the artificial intelligence model in order to increase the accuracy in predicting any diseases and help farmers make informed decisions. The proposed IoT system can not only monitor the health of crops but can also analyze the environmental situation and estimate the risks for any diseases among crops. In addition, with the combination of IoT with the AI system, smart irrigation techniques, alert generation, and precision farming are possible through the system. The live data from sensors is helpful in increasing the performance of climate-adaptive predictive analysis systems. IoT and artificial intelligence, along with sensing techniques, are an emerging field in smart agricultural technology for future use.

- **AI-Based Smart Pesticide Recommendation System:** The intelligent AI-based model of this research recommends pesticides, which is a novel technique to support sustainable crop farming and agriculture. While traditional plant infection models are designed solely for detecting plant infections, the new approach incorporates additional capabilities of offering the right pesticides for different situations depending on the severity of the disease and the condition of crops. The recommended pesticides are provided through an intelligent deep learning algorithm, considering various factors related to plant infections, such as crop types, disease stages, humidity, changes in temperature, rainfall, and soil conditions. Another distinctive feature of the model is that the pesticides offered within the system will be environmentally sustainable since the model recommends bio-based and organic pesticides wherever possible. The system also includes modules for weather forecasting, offering spraying suggestions based on the forecast of climatic conditions, so no spraying will be done under inappropriate climate conditions, such as rainfall and windy or hot days. In order to ensure the safety of the farmer and promote environmental awareness, this proposed system includes an advanced system for the toxicity assessment of pesticides, which can generate health risk alerts, safety guidelines for safety purposes, and environmental risk notifications due to the usage of pesticides. The uniqueness of this system lies in the use of the “Eco-Score Index” that has been created through the use of Artificial Intelligence. The pesticide can be assessed through a rating that is based upon its toxicity level, sustainability, effects on soil, residue level, and its overall ecological safety.
- **Federated Learning for Farmer Data Privacy:** This proposed system applies Federated Deep Learning methods in order to ensure farmer data security and privacy within AI-based smart agriculture systems. Under traditional AI-based cloud computing frameworks in agriculture, sensitive agricultural data belonging to farmers is usually uploaded to centralized servers in order to train AI models and make further analysis. The downside of this model is that it makes data leakage more probable. To mitigate the downsides of the aforementioned method, our proposed solution is based on the utilization of decentralized federated learning. In accordance with the principles of this approach, no data will be sent to centralized servers; instead, AI models are being trained on farmer’s devices using local algorithms, which will allow protecting sensitive data better.

Implementation of Federated Deep Learning can greatly lower security threats, increase system robustness, and increase farmer confidence about the use of AI for agriculture technologies. In addition to that, using federated learning will also help build trust among farmers as they will be in control of their farming data while the performance of AI models is improved through the federated learning process. Implementation of federated learning for crop disease detection system development is one of the emerging research areas in modern agriculture technology.

- **Climate-Adaptive Disease Prediction System:** This proposed study also emphasizes on the use of climate adaptive AI models which adapt to changes in environmental parameters such as temperature variations, uneven rainfall patterns, and climatic changes. With the use of adaptive deep learning algorithms, predictions of diseases can be made by constantly learning from the agricultural environment that is continuously varying because of climatic changes.

Conclusion

In summary, this review paper presents how artificial intelligence (AI), machine learning (ML), deep learning, and image processing technologies can be implemented in order to create an innovative crop disease detection system for smart agriculture. According to the findings presented by the author,

the early and accurate recognition of plant diseases is crucial because it helps to prevent the damage to crops and increase their yield quality while making agricultural practices sustainable. With the use of the latest technologies such as convolutional neural networks (CNN), internet of things (IoT), mobile applications, drone surveillance, and weather-based prediction algorithms, disease detection processes became more effective. Besides, there are numerous areas that could be researched in the future; some of these innovations include Explainable AI (XAI), Edge AI, federated learning, blockchain technology, multi-language farmers' assistance systems, and intelligent pesticide recommendation systems. All these innovations allow the users to make informed decisions without using too much pesticides and wasting agricultural resources. Furthermore, the combination of AI technologies with other tools can contribute to real-time monitoring, weather predictions, and climate-based disease prevention. In general, modern AI-based solutions for crop disease detection are highly promising in the context of smart and efficient agriculture.

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