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Applications of Artificial Intelligence and Image Processing Using Unmanned Air Vehicles (UAV) for Crop Health Identification

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ABSTRACT

Human survival and existence have depended on agriculture and livestock products since the early days of human civilization when they started cultivating land for various products. However, growth in population increased the demand for efficient agriculture production with high quality and quantity to meet the needs of society, and this cannot be accomplished through traditional methods. Hence, routine agriculture production methods should be changed to match the advanced methods in today's era. In this paper, we shall explore the technological advancement for assisting farmers during farming to utilize the technology fully; most companies are now involved in producing more intelligent and reliable devices to support and enhance the productivity of agricultural and industrial supplies. These solutions not only focus on providing real-time information about crop yield, soil health, pest management, herbicide resistance, weather forecasting, and weed management but can provide information based on the analysis of vast amounts of data available through drones and satellites. Artificial Intelligence and Image processing applications are yet to be utilized at their full potential for various reasons, including cost, availability, and awareness about the products offered by technology producers. While AI-driven and imaging methods have significantly enhanced the capability of monitoring plantations in developed countries, the usage of advanced methods can be cost-effective and increase the effectiveness of labor and time along with the usage of cameras for pest and disease identification, nutrient and yield monitoring related with inquiring about plant condition but undeveloped countries are still far behind in utilization of these advances in technology. This paper presents the current trends, challenges, and applications of technology in agriculture.

KEYWORDS: Smart Agriculture, Artificial Intelligence, Image Processing, Drone, UAV, Precision Agriculture

INTRODUCTION

Agriculture and industrial innovations have marked a new era for human civilization due to increased demand and supply of commodities. According to

the United Nations, the inhabitants of the world would be nearly 10 billion by the year 2050 (Talaviya et al., 2020); and that would be one of the causes that will drive many industries to increase their productivity to meet the basic demands. The growth in population will enhance the pressure on the usage of natural resources. Surprisingly, climate change is another factor that needs to be addressed. Its impact will lead to considerable challenges for humans to produce sufficient hygienic food to support the inhabitants in living healthy lives. The agriculture sector is utilizing 70% of freshwater supplies at present, which might not be possible at this level (Alreshidi, 2019).

Food safety and security require the agriculture sector to be efficient and sustainable. The key production sector of any country, including Pakistan, includes agricultural products as part of its Gross Domestic Product (GDP). In addition, 65 – 70 percent of the population depends on the agriculture sector and employs 38.5 percent of the labor force, along with a value addition of 19.2 percent in the overall GPD of the country (GoP, 2021)

In line with this initiative, the Government of Pakistan (GoP) has initiated an "Agriculture Transformation Plan" drive that will work closely to improve the agriculture sector according to the changing methods in the agriculture sector. Whereas, timely and reliable information regarding crop management, production, and yield is considered of great assistance to the stakeholders, and this will lead to the production safety and security of the product. According to the report (Mubarik, 2020), this sector is facing enormous challenges nowadays that conclude in terms of poor performance over the past few years, and the significant factors that influence such lower performance include no induction of technological innovations, problems with quality, quantity, and timelines of input supply, pest and livestock disease, marketing and trade restrictions, and lack of agriculture – specific loan products available for the farmers. The agriculture sector must address the complex changes and challenges in terms of the rise in population, changing consumer choices, economic growth, and water shortage (FAO, 2020).

With the advances in technology, most companies are now involved in producing more intelligent and reliable devices to support and enhance the productivity of agricultural and industrial supplies. Additionally, the European Commission has officially marked 2021 as the era of "Industry 5.0" due to key transformational innovations made within various industries, including agriculture. However, agriculture started at the time when humans began cultivation with the help of animals and wooden instruments, then after using metallic equipment for crop cultivation, and this was the time when agriculture started flourishing and was named the first and second agriculture revolution. The induction of robotics, telecommunication systems, genetic coding, and machines brought the third and fourth industrial revolutions, and the fifth revolution covers the application of agriculture remote sensing (RS). Artificial Intelligence and cloud computing (Martos et al., 2021). (Sharma, 2021) elaborates that artificial intelligence scripts the competencies of humans into machines. This approach defines a computer, robot, or any machine to act and think as humans do to solve a problem in a given situation. Machine learning is a subset of artificial intelligence where technology is changing faster and its significance is better (Pathan et al., 2020).

Smart agriculture combines technological aspects and devices nowadays to maximize crop productivity and reduce losses due to various environmental factors. Precision agriculture has a profound effect due to technological innovations, including drones, sensors, nanotechnology, robots, and hardware, which are used to identify weeds (Esposito et al., 2021). Remote sensing (RS) technology allows the monitoring of crops with various attributes, including periodicity of image acquisition, deployment of time and range, sensor distance from the object of interest, location identification, and extended coverage. In addition, it can perform real-time crop monitoring, disease detection, tree classification, yield estimation, water stress management, and nutrient and pest management strategies (Delavarpour et al., 2021). Although these advances in technology are in full mode, the significant challenge depends on the sharing of early information with stakeholders to initiate precautionary measures for eliminating the chances of disease and unwanted situations due to environmental changes. Artificial Intelligence (AI) and Image Processing (IP) have great potential to address the challenges faced by the traditional method of agriculture. While a significant amount of research has been conducted in the past decade related to the usage of AI and IP in the agriculture sector, there is a lack of studies that address the issues related to environment monitoring and pest control by using drones that are capable of using IP and AI techniques collectively. This paper intends to provide insights into the usage of this technique in environment monitoring and pest control.

RELATED WORK

This section of the paper presents an overview of the applications and challenges of Artificial intelligence and Image processing techniques in precision agriculture.

Impact of IP on Agriculture

New innovations supersede the old conventional methods in every field of life, including the agriculture sector, as advances are made in technology. Robotics and computer vision have periodically formulated new innovative approaches in agricultural land survey and data validation, but these advances are not publically used in underdeveloped areas of the world (Kakani et al., 2020). According to (Singh et al., 2020), however, digital image processing has been in practice for a long period of time. Various approaches were introduced, including advanced imaging using computing technology for better and more effective visualization of images in order to identify different plant diseases and deploying sensor imaging system for collecting the data from different aspects for study purpose. The data is extracted through image processing techniques, including image acquisition, pre-processing, segmentation, description, and classification. These techniques can enhance the efficiency of agricultural products by reducing the farmer's traditional monitoring of crops and improving the consistency and accuracy of the process. There are several applications of image processing that can be used in agricultural production for effective quality assessment, weed and crop classification, and fruit defect detection. However, the non-availability of online datasets makes it difficult to assess the quality of agriculture products that could be used in the testing and verification of image processing methods (Saxena & Armstrong, 2014)

Imaging Techniques

Crop production involves all activities that ensure quality yield in all seasons. It starts by analyzing the soil that will be used for crop production, the type of seeds, and nutrients for different crops according to their requirement. However, these yields are the main source for farmers and other stakeholders, but all crops face several challenging issues and crop diseases; thus, it requires a major focus on the agriculture sector by using the latest technological approach (Singh et al., 2020). In order to address various issues that arise during crop production that might be difficult for humans to deal with, image processing methods are used collectively with other instrumental and mechanical devices in order to automate the process for reducing human efforts (Du & Sun, 2004)

While imaging techniques are not limited to the agriculture sector only but are also practiced across various industries, including health.

The process of actual image collection is done through image acquisition followed by image processing technique, as shown in Figure 1. There are very useful imaging techniques consisting of fluorescence imaging, visible imaging, thermal imaging, hyperspectral imaging, multispectral imaging, 3D imaging, remote sensing, and MRT are being tested in various fields, including agriculture (Singh et al., 2020). According to (Talaviya et al., 2020), the method through which the image is acquired is related with the use purpose, and each imaging technique is different from one to other such as remote sensing technique is used for estimating geo-biophysical uniqueness and extracting crust features using electro-magnetic radiation; and recently developed drones have replaced the methods of traditional satellite imaging system due to finer stability and results. While these imaging methods have significantly enhanced the capability of monitoring plantations in developed countries, and the usage of advanced methods can be cost-effective and increase the effectiveness of labor and time along with the usage of the cameras for pest and disease identification, nutrient and yield monitoring related to inquiring about plant condition. While there are several single and multiple plant-capturing methods, such as direct leaf with and without artificial light measurement through UAVs and above-canopy measurement from a high surface, these methods have pros and cons in object capturing (Taruna et al., 2020). While, keeping the quality of yields and increasing its productivity enforces keeping them safe from various diseases. These diseases are one of the reasons to damage the crop growth and quality process. Large field crops require timely management of activities in order to watch them from disease and find the immediate cure and solution for such undesired challenges, which might have an effect on the overall functional and productivity capacity of the plants. These issues are quite difficult to tackle nowadays especially in large fields which require special modern techniques available for disease detection, similarity identification, image processing, and deep

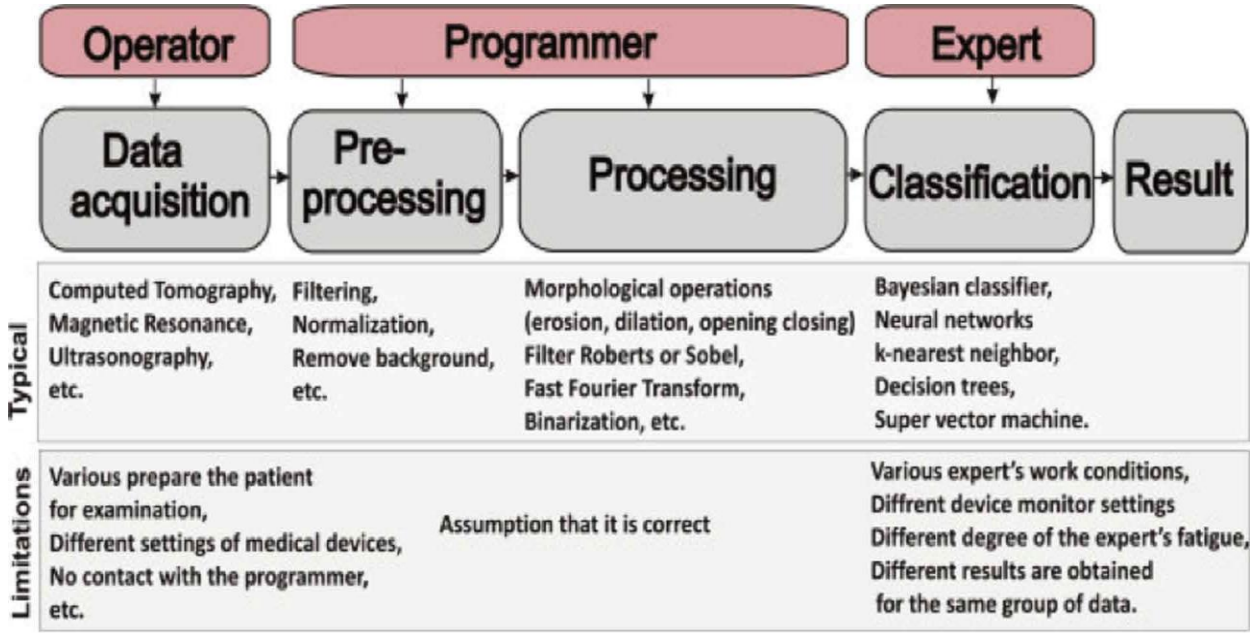

Figure 1: Image processing and analysis steps (Koprowski, 2014)

learning classification techniques by replacing the old and conventional methods (Singh et al., 2020).

Impact of AI on Agriculture

According to (Martos et al., 2021), the agricultural revolution began during the copper age when humans started using domestic animals and wooden instruments to cultivate the land, as shown in Figure 2. The current revolution is practicing cloud computing, agriculture remote sensing, and AI. The challenges faced by various industries, including agriculture, can improve functionality by adopting AI-based solutions developed over the past 50 years. however, challenges in the agriculture sector, such as lack of irrigation and drainage facilities, crop disease infestations, lack of storage management, weed management, and pesticide control, arise at different times during the yields (Jha et al., 2019). (Vadlamudi, 2019) elaborated that environmental monitoring is also one of the key issues in agriculture, and the use of AI in the environmental modeling approach is sustainable and supportive due to its potential and the way humans interact with our environment (Chen et al., 2008).

Furthermore, there is a serious disruption in agricultural productivity due to climate change. However, the inclusion of technology in all forms of life has made dramatic changes across various industries, but the agriculture sector has remained least focused in terms of the utilization of technology; on the other hand, tremendous development has been made in order to facilitate and achieve UN SDGs for zero hunger by 2030 through commercialization and growth in agriculture technology. (Vadlamudi, 2019); (Alreshidi, 2019).

According to (Vadlamudi, 2019), there are several technological developments for supporting agriculture productivity, including GPS/GNSS, robotics, irrigation, driverless tractors, mobile devices, UAVs, sensors, IoT, and weather monitoring modeling, the use of AI is relevant and efficient at the time when robots and drones are operational in the field. In addition, the role of AI is increasingly in demand across all industries, and precision agriculture utilizes the extracted data from the field for better decision-making. Therefore, the primary extent of precision agriculture is based on AI techniques, which makes it convenient for farmers to make smart and timely decisions. Meanwhile, AI concepts offer various options over time and consistently update those concepts in order to solve complex cognitive problems related to human perceptions. Additionally, the core activity of AI is to offer solutions to the problems that arise from time to time with the help of machines that think and act like humans. Thus, unlike conventional methods of solving the problem of the quality and quantity of food for people worldwide, AI offers smart solutions to address such issues efficiently and effectively.

APPLICATIONS OF AI IN AGRICULTURE

AI provides a source of creating intelligent machines to help and assist humankind to get the desired reliable and efficient results. Agriculture is also not an exception; the advancement in AI helps and benefits all the stakeholders to produce good quality food products. There are various applications of AI in the agriculture sector which are as under:

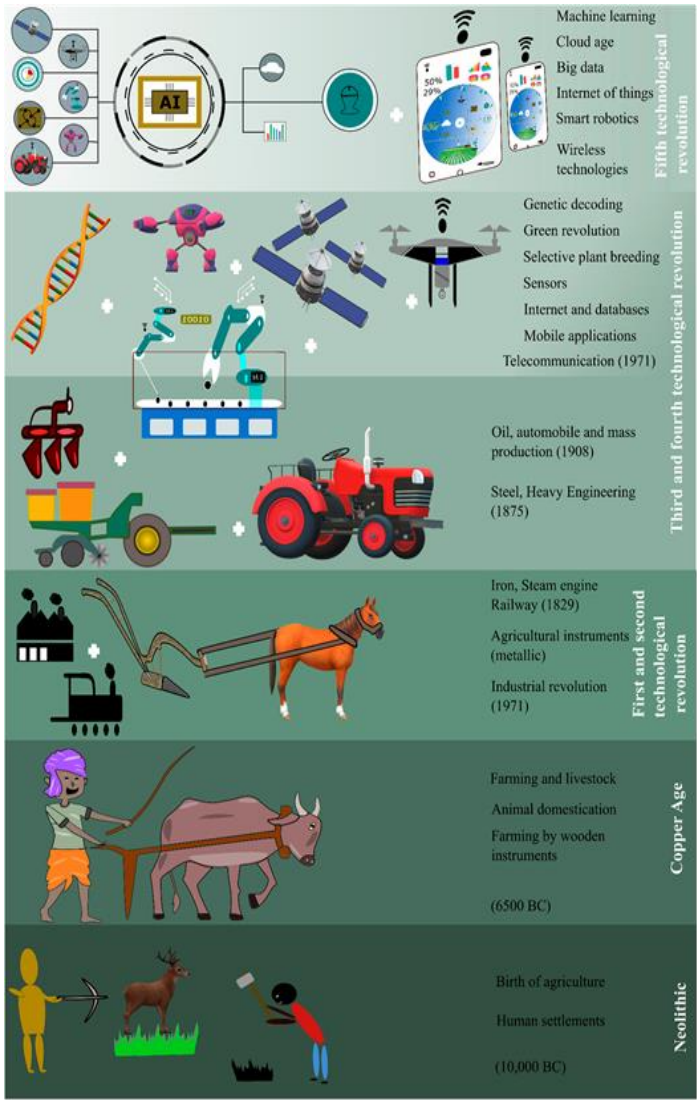

Figure 2: Agriculture Uprising Stages (Martos et al., 2021)

Crop and Soil Monitoring

Computer vision, deep learning, machine learning, and image processing are techniques through which data is acquired and processed with the help of sensors and algorithms in order to analyze and monitor the crops, soil health, and quantification of the land for harvesting. However, degradation and deforestation of soil quality is one of the key problems for many years. In order to address these issues, several developments have been made, such as a deep-learning-based image recognition application developed by a German company to identify the presence of pests, plant diseases, soil defects, and deficiencies. According to (Faggella, 2020), for the diagnosis of pests and soil defects, PEAT machines are used with Plantix application designed on deep learning concept that identifies potential nutrient deficiencies and defects in soil. In addition, trace genomics is another example of a technological application that provides detailed analysis of soil to prevent defective crops and help optimize healthy crop production. However, drones have been used in agriculture since the 1980s to leverage AI and drone technology to monitor the condition and health of crops. Drone technology helps in improving the crop yield by reducing cost and effort, and pre-program the drone's route by the user helps to get the updated images for better analysis.

Predictive Analytics

Analysis of data captured through various sources is helpful for monitoring the condition of the crops. Nowadays, machine learning-based models assist in tracking and predicting various environmental impacts during the crop harvest, such as weather conditions. AI applications such as: Where and Farm Shots are used for weather prediction, crop health, and sustainability monitoring. AI applications are important for crop and soil monitoring nowadays due to fast weather-changing conditions. However, the applications of technological advancement are uncommon in underdeveloped countries where conventional methods are being practiced to date, and stakeholders are unwilling to adopt these quick changes due to cost and difficulty in deployment. Drones and satellites generate data on a daily basis to enable the detection of potential threats and opportunities for crops and early preventive measures to keep them safe from undesired losses.

Agricultural Robots

Farmers always strive hard to control weeds, and herbicide resistance is a never-ending challenge for crop management. The application of robots and automation is to help farmers to protect their crops from weeds by using computer vision technology to monitor and precisely spray plants to prevent damage.

See and Spray robot developed by Blue River Technology helps in monitoring and spraying on cotton plants. Precision spray helps prevent herbicide resistance and reduces the cost through efficient and effective usage of resources.

Drones

Unmanned aeronautical vehicles (UAVs) or unmanned ethereal frameworks (UAS) is unmanned aircraft that can be operated and controlled remotely (Mogili & Deepak, 2018). The legitimate application of drones will create a total of 70 billion impact between 2015-2025 and the adaptability of drones will have a greater impact on agriculture sectors. Until now, the application of UAVs is large in agricultural settings such as irrigation equipment monitoring, crop health, weed identification, disaster management, and herd and wildlife monitoring have created huge impact on providing efficient and effective services to farmers (Talaviya et al., 2020); (Veroustraete, 2015). However, the promises made to the agriculture sector with regards to the deployment of drones will have a huge impact on the productivity of agri products have not been delivered at the maximum level due to various reasons, and a shift in regulatory policy of drone application is not practiced with full capacity (Veroustraete, 2015).

CONCLUSION

This paper provides an overview of various technological applications used in the agriculture industry, including image processing and AI-driven technologies. We have also presented various image-processing applications in plant disease detection and current trends and challenges. We have also presented AI-driven applications, including predictive analysis, drones, robots, and crop and soil monitoring, designed to solve the challenges stakeholders face. In the future, we intend to integrate drones with image processing and artificial intelligence techniques for pest-controlling and environment monitoring systems.

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