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The Convergence of AI, Machine Learning, and Neural Networks in Precision Agriculture: Generative AI as a Catalyst for Future Food Systems

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Abstract

Artificial intelligence (AI) has proven to be an efficient tool in monitoring crop growth and agricultural practices, but only focused on specific crop growth such as rice, wheat or maize. Furthermore, in these proceedings, AI mainly refers to traditional support vector machines, algorithms-based image analysis of data obtained through satellites mounted on drones. The proposed models use images from camera mounted drone video data and AI-based neural networks for a classification of beach crops in order to improve multiple crop growth monitoring.
Machine learning techniques have been used for classification of crop types in remotely sensed images for a number of years. One of the most popular successful methods for remote sensing (RS) classification is maximum likelihood classification. This method is used as the benchmark for comparison with a proposed model in a paper by, in which the study illustrates a method to measure the amount of overlap between two classes, boat crop and other crop for two different farms using six different band indexes. This paper uses the data in a novel. The image sampling method is used to convert a small clip of color digital image or video clip of the phase sampling to extract additional classes around the boat or other crop. This provides an increase in overall accuracy of at best 30% when compared to the benchmark of 58.84%. However, the implementation method is a complex process involving a shape file for study area definition, construction of sample 3 × 3 window for each pixel in the image to measure the overlap between classes which may not be readily accessible to general end users.

Keywords: Precision Agriculture,Generative AI,Machine Learning in Agriculture,Neural Networks in Farming,Smart Farming Technology,AI-Driven Crop Management,AgriTech Innovation,Sustainable Food Systems,AI-Powered Agriculture Solutions,Data-Driven Farming.

1. Introduction

AI, Machine Learning (ML), and deep learning (DL) have been applied to numerous industries, such as automotives, healthcare, diagnostics and security, in recent years and produce state-of-the-art results with high accuracy. However, these industries may not have an immediate impact on us as individuals, they do not solve natural disasters, or ensure that we have enough food to eat, or keep insects from destroying our crops, or stop diseases from spreading to our livestock. There is a tradition of using AI techniques with old and/or modified hardware in the agriculture industry to increase productivity, however less attention has been given to using AI to create new agricultural hardware instead. In this analysis, a new agricultural drone is created such that it can both play the role of a small-scale tractor and reduce the consumption of fossil fuels. There is an emergence in the agriculture market for "smart" farming or more precisely the use of AI to automate or optimize farming tasks in order to increase efficiency. developed a model that gave high-quality predictions for fields in Western Australia with the aim of determining a better scheduling of fungicide in order to stop the spread of yellow spot disease. The difference between attention is that feature channels are transformed through which attention is applied.

With the world population skyrocketing, transforming our food systems to be more productive, efficient, safe, and sustainable is crucial to mitigate potential food shortages. Fortunately, there is a realization that AI technologies like DL can play an important role in addressing these challenges. Recently, significant developments in data acquisition techniques including the Internet of Things (IoT), remote sensing, mobile, UAV, and social media have enabled the construction of big data in agrifood systems; in addition, sophisticated AI techniques have been proposed and applied in agrifood systems. With the data acquisition methods in place, AI models can go further in agrifood applications to, for example, improve the accuracy of disease identification for precision agricultural applications and predict the visual quality of products in post harvesting stages with a variety of machine learning and other image analysis algorithms on the edge semantic analysis device. However multiple methods, multiple data sets, multiple environments-produced complicated models with trade-offs between accuracy, interpretability, and sparsity. Various multiple kernel learning methods, not just the composite operator, were used to produce model outputs.However, all technology comes with side effects. Old farming machinery would become largely obsolete and weeds would evolve just as quickly as crops. All in all, the world is on the edge of watching its agri-system be revolutionized by today and tomorrow’s innovations.

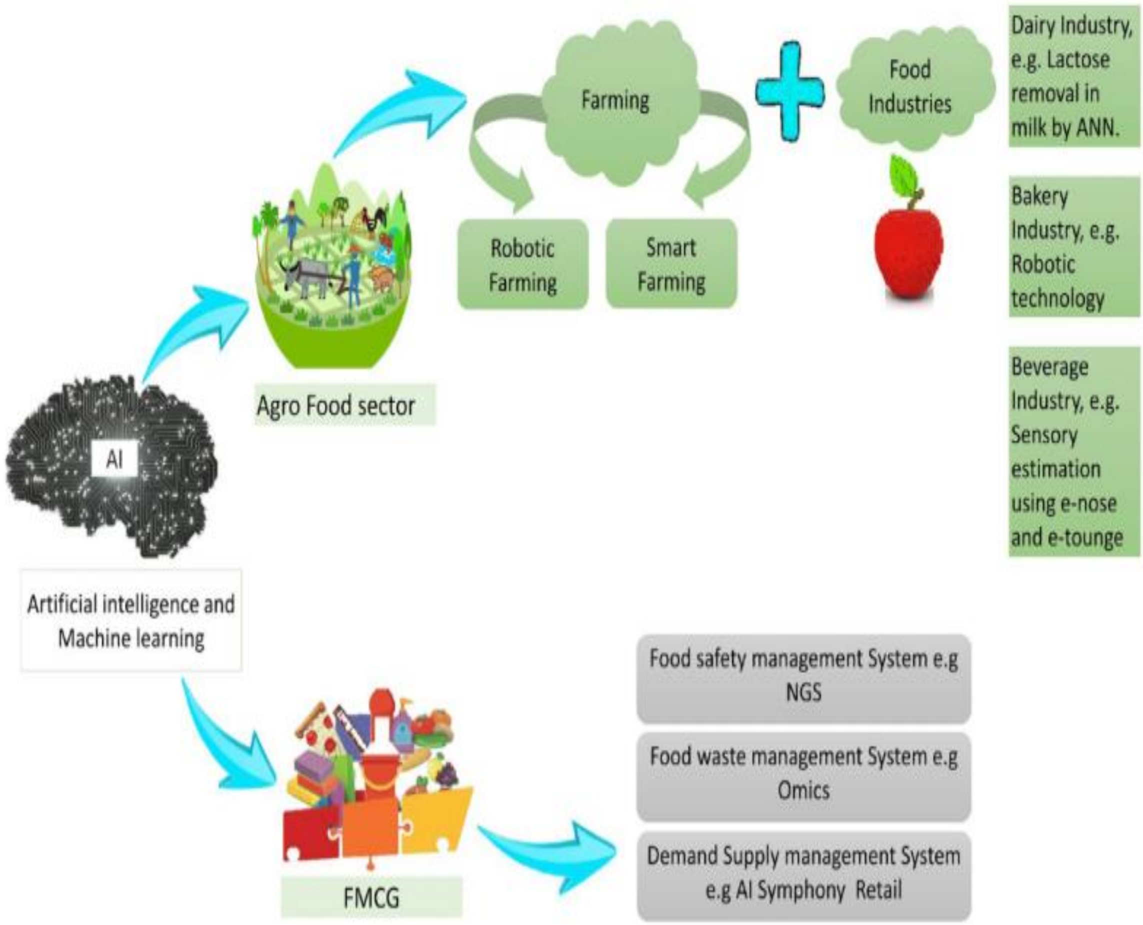

Fig 1: Artificial Intelligence Implications for the Agri-Food Sector

1.1. Background and Significance

The United Nations aims to ensure global food security while ending hunger and malnutrition by 2030. This is no small task, as at least 822 million people worldwide suffer from undernourishment. On the other side of the scale, 14% of the world's food is lost during processing and distribution annually. However, these numbers might soon be alleviated, as AI is on the rise. An emerging belief in the agri-sector is that AI, machine learning, and deep learning techniques have resources to revolutionize global food systems. AI in conjunction with machine learning and deep learning enables agri-forecasting, monitoring, optimization, and prescription at an unprecedented level. Generative AI technology has the potential to further boost AI and machine learning in agriculture. If you have ever owned a pet then you know just how quickly the costs of taking care of the animal rack up. From food to toys and trips to the vet, owning a pet is not cheap. So, the idea of holographic pets might be very appealing. But instead of simply entertaining children, the AI-infused holograms would provide children with knowledge of their real-life pets. No one would dare turn off a beloved pet hologram! To further save educators and disappointed children, if the real-life pet passed away, it could even be made to turn into a hologram itself.

AI, machine learning, and deep learning systems have found success in precision farming and (hopefully) will inspire the agricultural realm to avoid over-reliance on them. Several experts in the domain have looked into the potential of generative AI technology and see it as a major step to minimize the ongoing challenges AI faces. Generative AI is emerging as a rival treatment for knowledge-intensive medical and clearer applications.
When examining all the possibilities and impact, agriculture could be made far more predictable. From planting the perfect moisture level for a crop, to maintaining a set temperature and monitoring key stages of growth; with AI, feeding the entire planet is almost as easy as cooking a Sunday roast.

Equ 1: Generative AI for Crop Simulation (Generative Models)

$$\min_{G} \max_{D} V(D, G) = \mathbb{E}_{x \sim p_{data}(x)}$$

Where:

- G is the generator network.
- D is the discriminator network.
- x is real data (crop conditions or outcomes).
- $G(z)$ is generated data (simulated crop conditions).
- z is the input noise to the generator.

1.2. Research Objectives

Concerning research objectives, generative AI has been recently updated with the ability to create training datasets and infer new statistically indistinguishable samples. It is applied on global socio-economic data showing flood resilient agriculture enables mass decarbonisation while ending hunger with sustainability. It is combined with deep learning models to present efficient alternatives in numerous applications. With generative AI, the project aims to develop advanced frameworks that can indicate the preferences for best taste in a particular city given a user's movement and design a framework that can generate recipes. The broader impact of the results will inspire AI innovation, assist emerging food tech companies in developing sustainable business models, and assist users in discovering new and hyperlocal international cuisines.

2. Foundations of Precision Agriculture

Precision agriculture, or precision farming, is a contemporary technology of agriculture used for managing crop resources, such as water, sewage, pesticide, and fertilizer, to meet the particular needs of the field. Per its popularity, it coincides with the advancement of several technologies, including mechanization, sensor technology, hardware, and software development. The recent development of AI-based decisions by autonomous devices and Smart Farm platforms would permit the integration of AI to make automated decisions for precision farming. Digital agriculture is a future transformative technology envisioned in the agriculture industry supported by Machine Learning, IoT, AI, and data science. The convergence of generative AI, Machine Learning algorithms, and neural networks may bolster the digitized farming ecosystem and further develop data-driven agricultural solutions for resilience of food systems.

The history and different components of precision farming are introduced, followed by several aspects of precision farming's past and the present with a focus on the convergence of AI and Machine Learning in the agriculture industry. The advances in AI, Deep Learning, and computational processing capabilities have driven on-farm automation, which can eventually lead to a fully autonomous farming ecosystem. The convergence of AI and precision farming is a liberalization of the Industrial Revolution currently taking place in the agriculture industry and has led to the formation of digital or smart agriculture. It is a future transformative technology envisioned in the agriculture industry, creating an impact on almost every aspect of food production. To fully prepare and realize digitized farming ecosystems, it is essential to investigate the foundational technologies parallel to revealing the prospects and challenges. Advances in positive feedback of generative AI and intelligent farming equipment may meet, or exceed, the productivity of the conventional multi-layered food system. However, how these high-level agriculture decisions should be made and how they would converge is a critical elimination for smart and responsive food systems. Such a knowledge gap motivates the present discussion, which also considers the convergence of AI and Machine Learning algorithms for precision agriculture by investigating digitized agriculture decisions on the middleware platform to form or anticipate future agriculture recommendations.

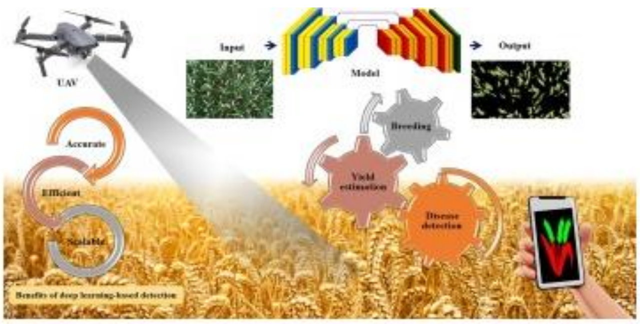

Fig 2: Advancing precision agriculture

2.1. Definition and Scope

The development of artificial intelligence (AI), especially machine learning (ML) and deep learning models such as neural networks, has been remarkably successful in areas including computer vision, speech recognition, and natural language processing. In recent years, applications of this technology in precision agriculture and in agri-food systems more broadly have also shown significant promise. Here, focus spins around the development of generative AI within agrifood systems, recognizing two converging trends. On the one hand, generative models are becoming more capable and reliable. Technologies like Generative Pre-trained Transformer version 3 (GPT-3) can now generate text with human-like coherence on a wide range of topics. Moreover, counterintuitively, better generative models can also create more errors or false content that amplify the scale of disinformation generated by the AI. On the other hand, two nascent agricultural spectrums amplify the potential impact of generative AI and contribute to the ascendency of machine learning-powered applications in precision agriculture and agrifood systems. This article explores these converging trends and discusses the possible risks and benefits associated with the development of generative AI in agrifood systems.

The generation spectra governs the relationship between generative AI and an audience. On one side, the AI can generate content with human-readable text, tabular data, images, or audio that is obtained passively. This may take the form of human-generated or user-uploaded training data and evaluation content, e.g., customer text reviews, precision agriculture data sets, or agri-food system yield reports. For ML models trained on this data, generative AI means generating novel outputs in the input training data category. This might involve creating new human-written articles on similar precision agriculture or agrifood topics, urban agriculture growth stage image synthesis, or forecasting novel textual perceptions based on user-generated restaurant reviews.

2.2. Traditional Approaches vs. AI Integration

The development of Information and Communication Technology (ICT) brings transformation and modernization to nearly every field such as agriculture. Particularly, Artificial Intelligence (AI), which refers to machines with intelligence imitating cognitive functions of humans, including learning, reasoning, problem-solving and perception, has been growing significantly in agrifood systems. Machine Learning (ML) and Deep Learning (DL) are subfields of AI. Machine Learning is a type of machine intelligence system that is capable of automatically learning from data and providing a prediction of future trends given past and current data. Deep Learning is a subset of Machine Learning, which provides a common way to mine large-scale data of various types for knowledge or insight, especially in a predictive situation. Applying AI techniques into agriculture provides means of letting a system operate autonomously by scouting the area and detecting faults regarding different soil parameters, damper contents of the soil, crop status or parasite presence, thanks to the qualified sensors. Traditional prediction methods aim to describe the data without considering the potential information in the data. They are not reliable or robust, especially for the multidisciplinary systems existing in agriculture. A major barrier to the proliferation of AI in agriculture is data acquisition since a large amount of labeled data are required for training. Artificial Neural Networks (ANNs) imitate the human brain to identify complex patterns, which are suitable for handling noisy input data. However, ANN methods seem to have reached their limit with an expected Tight upper bound on their performance. With the development of sensor technologies, large-scale multi-dimensional data can be collected on region-level scales at unprecedented spatial and temporal details. Current approaches such as support vector machines, random forests, or typical ANNs can no longer efficiently process and take advantage of these data. Some stated that integrating AI into agriculture would increase inefficiency, energy consumption, and environmental consequences due to the high energy requirements and large data sets necessary for training. AI applications were still in the process of transformation or adoption by the agrifood industry. Efforts to boost efficient food classification, prediction, delivery, recipes, and wastage in the agrifood industry by applying AI have failed so far to show significant positive results.

3. AI and Machine Learning in Agriculture

The convergence of Artificial Intelligence (AI) and agriculture results in politically charged narratives around technology-driven solutions developing nations should pursue for food sovereignty. Contrary to this determinist vision, different experience-centered narratives have emerged, arguing for farmer-driven, context-specific, and rights-based solutions. Most innovative is generative AI, a technology based on neural networks that can identify inequalities across digital supply chains and respond to requests throughout living systems. Seeing food systems through a generative AI lens reveals their cognitive imprint and triggers questions around decolonization, mass declassification, and agency in a future where food rights may depend on people's capacity to generate it. Machine learning (ML) is a subset of AI, a discipline used in agriculture to make precise decisions based on strong underlying conditions. It requires computational intelligence along with the understanding and actions, a set of cognitive abilities. AI delivers these abilities to machines, allowing them to learn and thus understand, learn and thus make decisions and respond in a way humans do to varying situations. Available AI is not limited to ML but encompasses Deep Learning, NLP, Computer Vision, Fuzzy Logic, Expert Systems, Swarm Intelligence and a host of related computational techniques and algorithms. AI has now grown to be the most pervasive

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technology in everyday life, facilitating precise actions in various sectors, and food agriculture is certainly no exception. A new era of food systems has been on the horizon with the advent of generative AI, a novel approach to AI built on fundamentally new neural network architectures with the latent capacity to uncover inequalities across all digital supply chains and write responses throughout all living systems.

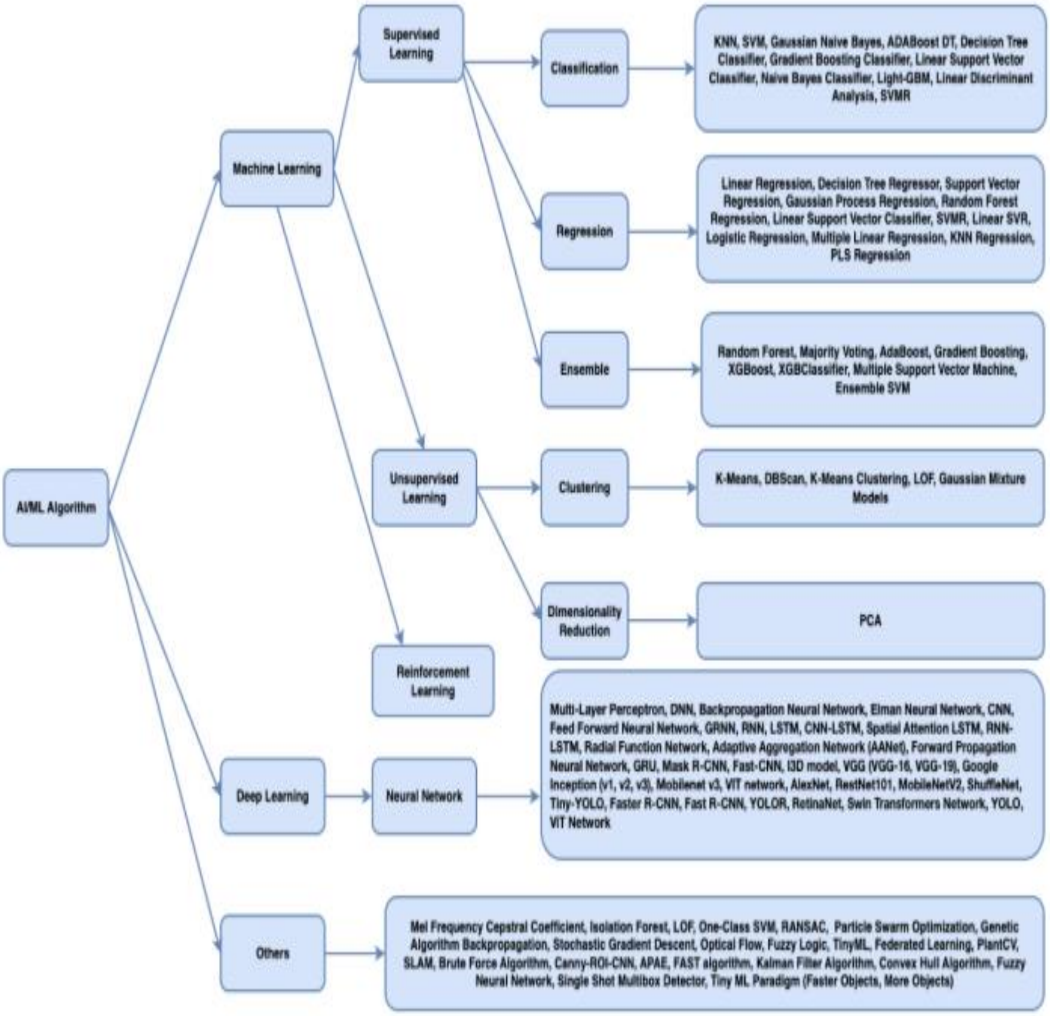

Fig 3: Artificial Intelligence Technologies for Precision Agriculture

3.1. Applications in Crop Monitoring and Management

Precision agriculture is an integrated farming system that, using modern technology, captures, integrates and processes real-time and spatial data that need to work efficiently, sustainably, and in force to maximize crop yield with minimal resource consumption. It also increases the sustainability of agricultural food products by minimizing environment pollution and reducing the use of pesticides, fertilizers, and water. Precision agriculture is the establishment of an efficient automatic network monitoring system in the field, which involves sensors, cameras, and imaging technologies that are seamlessly integrated with data processing systems. These devices allow for real-time monitoring and analysis of crop conditions, soil types, and many other farming aspects. Thus, the obtained information can greatly improve the understanding of the ways to manage the use of resources. More precisely, continues, valuable insights into the state of health of the plant in terms of germination, pathogens, pests, and diseases help to detect the symptoms of these problems and guide control measures. Machine learning (ML) algorithms and methods are used on data elements to take advantage of the information gathered by digital agriculture. Decision support systems (DSS) for various agricultural applications related to crop monitoring were developed. ML and artificial intelligence (AI) systems were designed to collect comprehensive data about crops, pests and diseases, and to interpret that data to make decisions. Because of rapid progress in digital agriculture, the integration of multi-robot systems into precision agriculture has recently gained considerable attention. In conventional agriculture, farmers have one or a few machines for their work in a large field. However, the necessity of using multiple robots with unique capabilities is crucial in precision agriculture. To improve the accuracy of product selection, the robots are divided into tasks, and various data management systems are generated to optimize or access the desired positioning.

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3.2. Advancements in Precision Agriculture Technologies

Climate and environmental changes have greatly affected agriculture over the years; thus, it is a must to integrate advanced technology into agriculture to address these concerns. The seamless convergence of artificial intelligence (AI), machine learning (ML), and neural networks (NN) is offering promising hope to precision agriculture, mainly focusing on increasing productivity and cost-effectiveness through the temporary allocation of resources among precise settings of agricultural lands. Thermal and hyperspectral imaging is a quick and competent way to procure vast and accurate information about crops.

The proposed workflow is designed to handle and process image data through a fully-fledged computational edge computing model powered by NVIDIA Jetson Nano for concurrent and future use. The model's robust and versatile set of configurations can be employed with thermal, multispectral, and hyperspectral images to assist in the development of various machine learning models for agricultural applications. The future work aims to bridge the gap in ambiguity by augmenting Generative AI models to simulate / generate farm data and to curate the data on low-cost production of multiband cameras.

Equ 2: Crop Disease Detection (Convolutional Neural Networks - CNNs)

$$y_{i,j} = (W * X)_{i,j} = \sum_{m,n} W_{m,n} \cdot X_{i+m,j+n}$$

Where:

- $y_{i,j}$ is the output of the convolution operation
- $W_{m,n}$ is the convolutional filter (kernel).
- $X_{i+m,j+n}$ is the input image.
- $*$ represents the convolution operation.

4. Neural Networks and Deep Learning

Artificial neural networks are machine learning models based on the analysis of data, predictions or decisions that model themselves inspired by the brain and processed by neurons. Here are some points on understanding them and their subfields like deep learning, used as models, algorithms, and their relation to AI. Although the fundamental basis of operation is the brain, the technology for creating and understanding these networks on a mathematical basis was only mathematically discovered in the 20th century, in the years 1920 and 1950. The theory of neural networks further pervaded the masses around the 1980s with the boom in studying artificial intelligence and computer science related neurology. The late 80s could be characterized as the winter of AI since a lot of projects had bombed and many ideas were discredited, but many of the core concepts had been expanded in this time and thinking about their application grew. This includes a course in neural networks, which resulted in the establishment of Google by students. That is in its initial form, since Google owed much of its informational structure to the inspirations developed during this neural network research. Most of the work done in AI is based on the models and algorithms created by neural networks with its subfield deep learning.

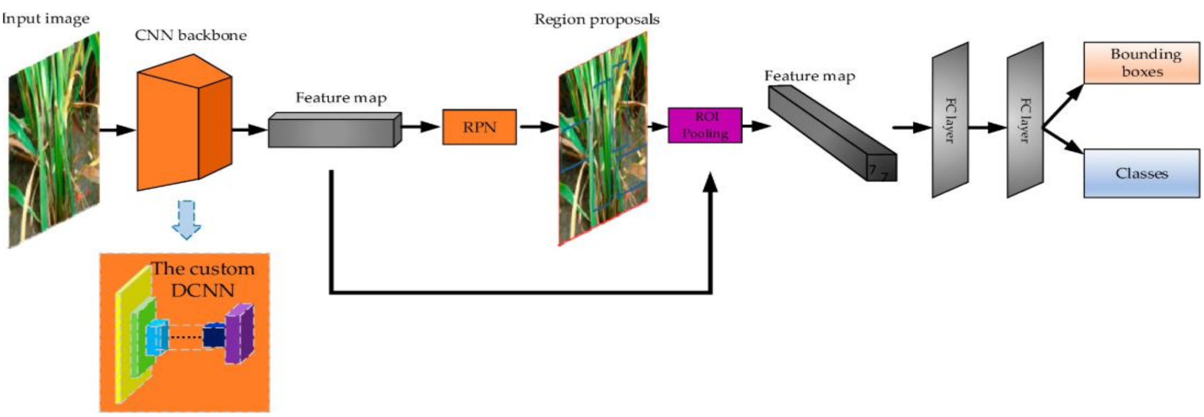

Fig 4: Convolutional neural network in rice disease recognition

4.1. Fundamentals of Neural Networks

As a subclass of artificial intelligence (AI), machine learning (ML) carries out the learning and predicting tasks on the basis of the experiences of a dataset. Various learning approaches have been devised, and deep learning (DL) has become the unfavorable option for various scenarios due to the superior learning capacity brought by neural networks. A neural network comprises three crucial components: an input/output layer, an intermediate layer, and an activation function. The input/output layer is designed to process the input data and produce the output data. The intermediate layer involves multiple neuron nodes, serving as the data transformation device. Weight and bias are assigned to each neuron for data processing. An activation function is designed to evaluate the integrity of the data provided by the previous layer and introduce certain nonlinearity. Following the above steps, the data are generated in the form of the probability distribution and the welfare model has been built. However, many drawbacks may be encountered when using a DL model to produce data. For example, DL models work in accordance with the data of a fixed format, e.g., the resolution value of computer vision. Although neighboring DL models can contend with the different formats of the data, the data of minute processing needs to adhere to the neighbor model. The flawed DL model requires a synthetic picture to take advantage of the economic utilization.

The generative AI method is developed depending on the adversarial network generator, offering capabilities in generating artificial samples from training samples. In recent years, several issues regarding the AI and ML pattern associated with the agrifood field have been reread. The prevalent examination on AI and electricity originated from deep learning, encompassment learning, and cognitive computing. That paper diverges from preceding discussions by examining the generative AI assemblage. Moreover, various original and recondite terms are specified to encourage understanding. People devoted to AI science or technological savoir faire should they may derive to further understanding and surient the essential AI knowledge.

4.2. Deep Learning Architectures in Agriculture

In the last review, a broad trend was shown regarding different studies that proposed deep and novel architectures. In that sense, in 2018 and 2019, various deep learning architectures and applications of them in agriculture were summarized. 2D, 2.5D, or 3D deep learning architectures were implemented for agriculture in various applications like plant disease detection, fruit detection, weed recognition, and classification of several field crops. are basic architectures that are widely used in practice. New deep learning networks emerged based on stacking or combining them with different layers in nuance like .

5. Generative AI in Precision Agriculture

Since the inception of AI (Artificial Intelligence) with the basic concept of machine learning, it has continuously driven neural networks to learn complex patterns. The field of AI primarily uses machine learning and deep learning for better understanding. Thereby, it resulted in many applications enriched with intelligent systems. AI is a functioning precursor that leads to demonstrable inventions such as driverless cars, robots, and concurrent device intelligence. Remarkably, AI is considered a major precursor for altering the contemporary world with practical innovative ideas.

This article addresses the application of generative AI in precision agriculture along with machine and deep learning. The role of AI, machine and deep learning is discussed, followed by the potential implementations along with generative AI results in precision agriculture. Additionally, discussion on the IoT revolution and AI-driven revolution, AI-driven generative models in precision agriculture, potential implementations in precision agriculture with GANs, and reflection of AI-driven models are presented.

With the dawn of the Fourth Industrial Revolution (4IR), AI has become an inevitable mapping for the contemporary world. In the present era, AI is keen on modern inventions associated with smart healthcare systems, robotic counselors, gene-based diet recommendations, and autonomous vehicles. Most significantly, AI is a need for modernized applications designed with an intelligent device system. In the near future, AI is foreground as a base for performing robots, independent investigation devices, smart factories, and knowledge-based systems. As a matter of fact, since the initiation of 2020, significant economic and social transformations are rapidly varying the entire world. Therefore, a bottom-up revolutionary alteration with intelligence-based automation is foreseen for the modern world. Since subsequent to the industrial revolution, the transformation of intelligence-driven devices has become progressively consistent.

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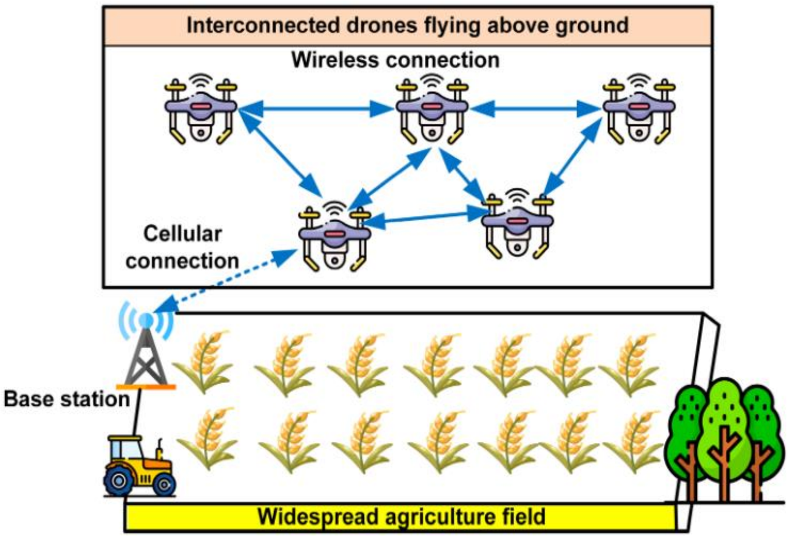

Fig 5: AI-Powered UAV Technologies in Precision Agriculture

5.1. Concepts and Principles

1. Delivering a sustainable future food system will require the convergence of several technological breakthroughs and socio-political innovations. This includes the adoption of artificial intelligence, machine learning, and deep neural networks, as well as more holistic food chains and diets. The inclusion of these more complex causal dependencies in food-related policy models will promote better policy decisions. Artificial intelligence has the potential to improve the efficiency, safety, and sustainability of many types of production and consumption systems, although developing and applying it in a truly beneficial manner is far from guaranteed.
2. Mass produced by standard techniques can propagate and exacerbate multiple existing social, economic, and political inequalities. As one core element of artificial intelligence, machine learning and particularly deep learning arrived into the entomology and agronomy fields only recently. These networked systems of mathematical functions inspired by the human brain were first used for training artificial visual and auditory perception. Better image classification and speech recognition software cascaded into a plethora of improved, speech-to-text, recommendation, and predictive analysis services. Some time later, researchers saw the potential of these convolutional and recursive neural networks for time series data and transferred the methodology to hydrological and climatological problems in the earth sciences.

5.2. Potential Applications and Benefits

Agriculture has special meaning as the foundation of ecosystems and economies. The continuous increase in the population of the world is a major issue to be faced. As a consequence of rapid population growth, there is a corresponding increase in demand for agricultural products. In these conditions, accurate irrigation scheduling and water use efficiency are increasingly important. Precision Agriculture, along with advanced technologies in the fields of IT, robotics, AI, Online Decision Support Systems, remote sensing, the internet and digital technologies generated by the Industry 4.0, is regarded as a promising method for monitoring, control and management of agricultural practices. Farm management practices, which depend mostly on human resources and external conditions, will be possible to manage more accurately and easily by the use of technology with the development of the necessary infrastructure. However, Precision Agriculture is multidisciplinary and combines specialized knowledge in agricultural and environmental issues, digital agriculture data, computer sciences, agroeconomics.

Throughout generations, AI has become conventional, from the advent of self-driving cars to virtual assistants. Agriculture is a field that most benefits from AI. AI features enable decision-making based on varying conditions in comparison to traditional approaches, which make fixed decisions. The essence of AI, machine learning (ML), and neural networks (NN) collectively provide solutions to the complexities of agriculture. AI, the academic study of computer systems that emulate the intelligence of humans, is one of the main technologies that possess computational intelligence. ML blurs the line between expert systems and general patterns to learn from data and predict new results. At present, the implication of NN is mainly used to learn the underlying pattern amidst vast datasets. To meet food requirements, humanity's focus is shifting to introduce future food systems, whereby AI, ML, and NN will play a pivotal role.

Equ 3: Precision Agriculture Feedback Loop (AI and Sensor Data)

$$u(t) = f(y(t), \theta)$$

Where:

- $u(t)$ is the control action (e.g., adjusting irrigation, fertilization).
- $y(t)$ is the system output (e.g., soil moisture or crop health).
- θ represents the model parameters (e.g., AI model coefficients).

6. Challenges and Ethical Considerations

This work can have far-reaching consequences for the future of the world's food supply. However, in addition to technical challenges, there are also a number of ethical considerations chefs, farmers, and scientists should be aware of when investigating generative AI's role in agronomy. Responding to the increasing demand for food from a growing population in the coming decades poses a major challenge. To feed the world's population by 2050, it is estimated that food production will need to increase by 56% compared to 2010 levels. Food systems account for around 25–30% of global greenhouse gas emissions and are responsible for significant non-renewable natural resource consumption. Food systems also have extensive social implications, with around 690 million people on Earth currently going hungry, and many more suffering from malnutrition. Generative AI has great promise to enable food systems to transform the way they operate and move towards more sustainable outcomes. This involves the overarching objective of making food systems more carbon, water, ecosystem, and resource use efficient, as well as increasing productivity and efficiency, while ensuring that the resulting food is nutritious and safe. It also encompasses the aim of ensuring that farmers receive a fair income and simultaneously protecting consumers from spikes in food prices as a result of environmentally induced product shortages. So far, generative AI has transfixed consumer end-use applications. However, the sequencing of complete genomes of crops and pests, coupled with increasingly detailed monitoring devices, has now yielded an unprecedented amount of data on plants and the systems in which they grow. Although some rudimentary models exist, data of this scale becomes intractable to many traditional statistical approaches and computational platforms. This presents a unique opportunity to employ generative AI, which has shown great success in more conventional big data settings for natural language processing and image and speech recognition.

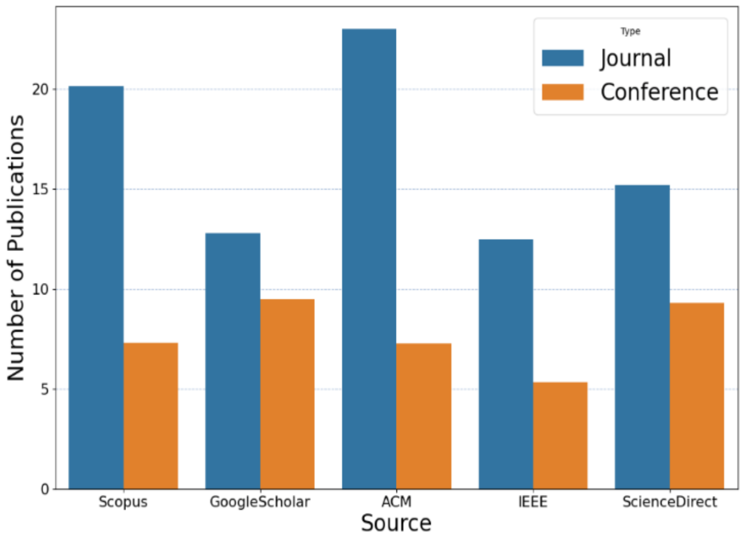

Fig : IoT Solutions with Artificial Intelligence Technologies for Precision Agriculture

6.1. Data Privacy and Security

Data collected and processed must be kept somewhere, usually in the cloud, on the edge or on on-premise servers. Given the importance of data in the field of smart farming, the need to have more data to treat and analyze a situation has a big impact on the amount of data stored by a provider. Consequently, hosting companies have to invest massively in hardware, software and electric power and in the end, these expenses are directly or indirectly transferred to the users. However, one has to acknowledge that farm data can be used to better other field players: seed providers to improve their varieties, institutions to help in the allocation of new grants to promote sustainable agriculture, and more generally the academic world in order to go further in the understanding of natural phenomena. Thus, two opposite forces are at stake for today's data handling and sharing in agriculture. Data must be stored in a secure environment to respect trust with providers and privacy regulations, but also new tools and standards are needed to enable emergence of new uses based on data access.

6.2. Bias and Fairness in AI Systems

Artificial intelligence (AI) and automatic machine learning are emerging disciplines and technologies employing computational models and procedures for learning from data to make decisions and predictions. Neural networks are a set of algorithms, modeled loosely after the human brain, that are designed to recognize patterns. They interpret sensory data through a kind of machine perception, labeling raw input. One major limitation of using neural networks in applications is due to the absent analytical solution, which makes the training process challenging. A generative model accepts input data, and generates new samples that are highly correlated with the input data. Generative AI can be trained quickly with small datasets, while its performance is competitive with state-of-the-art models when training with vast amounts of data. When it comes to precision agriculture practices, governments should promote programs aiming to increase the diversity of agriculture investors whether this is through providing knowledge or financial aid. Multiplex networking platforms should also be implemented to encourage the sharing of smallholder knowledge amongst themselves and with large-scale players. Governments should subsidize and encourage the deployment of advanced technological equipment on smallholder farms, which will help mitigate the gap in technological inequalities between large and small-scale farms. By investing in the future of smallholders, the large-scale agricultural sector will also benefit in the longer run.

7. Future Directions and Conclusion

Revolutionizing agrifood systems to be more productive, efficient, safe, and sustainable is crucial to mitigate potential food shortages. In the past few years, artificial intelligence (AI) techniques, especially deep learning (DL), have shown strong abilities in many applications related to agrifood systems. However, the overall impact and potential challenges of AI application on agrifood systems are not clear for various stakeholders, such as policy makers, funding agencies, and researchers in computer science, engineering, and agronomy. This article comprehensively reviews and discusses how AI techniques, especially DL, can transform agrifood systems and consequently contribute to the development of the modern agrifood industry.

Big data is the key feature of AI applications in agrifood systems. A large quantity of data is generated in the entire agro-production process, such as land-based operations, feed formula preparation, seed selection, and breeding guidance. To apply AI techniques on agrifood systems, it is important to address the data acquisition problem first. On the one hand, massive data is recorded and collected in batch by various sensors, satellites, UAVs, tractors, and combines during the agro-production process. The acquisition techniques of multi-source data in agrifood systems are firstly summarized, such as hyperspectral imaging, compound eyes, and Internet-of-Things (IoT). On the other hand, multidimensional data is not directly usable by AI models and needs to be preprocessed, filtered, or transformed before input. So, the corresponding storage and processing techniques are also reviewed in detail.

AI methods have a significant application in the field of agrifood systems. A progress review of AI methods in agrifood systems is provided and advances are mainly summarized in two aspects. On the one hand, the AI methods can be applied to various segments of the modern agrifood industry, namely agriculture, animal husbandry, aquaculture, distribution, and trade. On the other hand, the research is in the analytical framework, that is, how the AI methods can help the development of agrifood systems (e.g., sowing-pest control-harvest warehouse-delivery).

The results of AI techniques in the review are largely built upon the classical realizations and massive data models. To further boost the transformation of modern agrifood systems, it is necessary to explore and expand the research from these perspectives into the consideration of several important potential challenges and provide corresponding research opportunities.

7.1. Emerging Trends and Technologies

The world population has been increasing rapidly, and there is a strong connection between larger populations and the demand for food. While unparalleled progress has been made, the food production systems continue to face challenges such as low yields and declining soil health. AI technologies have effectively coupled with big data to help build agricultural decision support systems that contribute to the overall efficiency of food production. It was mentioned that with the rise of new technologies like AI, IoT, and drones, huge and complex data can be acquired. Generative Adversarial Networks have been explored. In the field of smart agriculture, most of the existing literature introduces data acquisition and analysis rather than discussing the generated data itself. To bridge this gap, a comprehensive review is provided on the latest Generative Ai (GAI) methods contributing to optimal processing and prediction in agriculture.

Recently, there is a notable increase in research on AI technologies to solve optimization problems within industry from both academia and industry partners. While past methods were focusing on embedded control systems in individual devices, research progress on AI IoT is rapidly increasing due to rapid development of IoT devices, cost-effective computing infrastructure in the cloud, and advances in AI-related algorithms. Various advanced AI technologies have been explored that converge with IoT. Machine learning and its subseries deep neural networks are cleverly used in various image processing/analysis to extract more meaningful information from raw images. On the contrary, in a feedforward network, an attempt is made to implement a function approximator y=f(x) that tries to learn a to-be-labeled dataset.

7.2. Implications for Future Food Systems

The conversion of AI, machine learning, and neural networks into generative systems would represent a unique and promising addition to genetic algorithms. Generative adversarial networks (GANs) would appear to be the most prominent generative artificial intelligence (AI) application and offer great promise as a transformative technology for agriculture and wider agrifood systems. The current approach to machine learning (ML) typically requires copious amounts of annotated data, the availability of which is both implicit and demanded by the big-brute force and econometric modeling assumptions. However, GANs, by contrast, are trained on broadly unlabelled datasets and operate as unsupervised models, generating high quality, synthetic data, even before the training algorithms have converged. Additionally, the robust and ever-changing biological systems resist simple linear and nonlinear modelling. Although currently still in their relative infancy, the use of GANs has the vast potential to disrupt existing agricultural and wider agrifood systems that they mature and become more ubiquitous across research, industry, and development. With the world’s population predicted to reach over 9.7 billion people by 2050 there are a number of pressures on agrifood systems, including biological (pests, diseases, climate change), economic (globalization, commodity prices) and ecosystem (freshwater scarcity, pollution, bio-intrusion, deforestation), which are interlocking and potentially synergistic. Therefore it is critical to transform existing systems to be significantly more efficient, productive, safe, and sustainable . The global demand for food to underpin humanity’s needs will grow incessantly, and so the “future food systems” concept will require profound changes to ensure the “safe, sufficient, nutritious and sustainable [production of] food” for all.

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