CHAPTER

Robotic Systems and Artificial Intelligence Applications in Agriculture

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Introduction

Two significant transformations have occurred in human history. The first is a process known as the agricultural revolution, while the other is the industrial revolution, which significantly reduced the population engaged in agriculture worldwide, transforming people into individuals increasingly involved in production and manufactured goods. The latest stage of this transformative process is marked by advancements in science and technology, particularly in the fields of robotics and artificial intelligence (Güran, 1990).

Artificial intelligence refers to an engineering discipline that transfers human intelligence characteristics into computer systems and develops algorithms. Robotics, on the other hand, is a field encompassing various disciplines, aiming at the production, design, and utilization of intelligent machines to perform tasks typically carried out by humans.

Artificial intelligence systems are structures that analyze the cognitive functions of human intelligence through computer models, integrating these abilities into different systems equipped with human-like capabilities such as information gathering, perception, learning, thinking, and decision-making (Bozüyük et al., 2005).

The artificial intelligence methods used in artificial intelligence applications are categorized as follows: (Alpaydın, 2004):

- Classification is the process of determining which class new data belongs to by specifying the classes of past data.
- Clustering, on the other hand, involves grouping data based on their similarities when past data hasn't been classified or is unknown.
- Regression or curve fitting involves creating a curve model from past data when the data consists of continuous numerical values.
- Feature selection involves identifying the features that affect classification in large datasets. This process may involve creating subsets from existing features or deriving new features from their combinations.
- Association inference involves analyzing relationships between data to identify the most frequently occurring data together.
- Agriculture is defined as the entirety of activities conducted on land to obtain necessary plants to fulfill humanity's vital needs.

Artificial intelligence is a fundamental research field in computer science, rapidly spreading due to its strong applicability in solving problems that are difficult for humans and in traditional computing structures. One of these areas is agricultural activity conducted on 2,781 million hectares of agricultural land, where 30.7% of the world's population works. The agricultural process involves various challenges, including pest and disease control, chemical management, weed control, yield predictions, and irrigation errors. (Bannerjee et al., 2018).

Various technological devices are utilized in the agriculture industry. Equipment such as tractors, combines, harvesters, fertilizing machinery, irrigation systems, agricultural aircraft, farming robots, and agricultural sensors are included in these tools1. Within the agricultural sector, an approach known as precision farming enables the optimization of agricultural processes by collecting and analyzing field data through sensors and unmanned aerial vehicles (drones). Additionally, the use of artificial intelligence in areas like weather forecasting, irrigation management, and soil analysis is becoming more prevalent. Artificial intelligence facilitates the early detection of plant diseases and pests in the agricultural sector, thereby optimizing intervention processes for farmers (Kocaoglu, Gumuslu, Guven, Baz, Erol-Barkana, & Soğutmaz-Ozdemir. 2021).

The agriculture industry can be managed more efficiently, sustainably, and intelligently with the assistance of artificial intelligence technology. Artificial intelligence is employed across various domains within the agricultural sector. For instance, an approach known as "precision farming" optimizes agricultural processes by collecting and analyzing field data through sensors and unmanned aerial vehicles (drones). Additionally, the use of AI in areas like weather forecasting, irrigation management, and soil analysis is increasingly prevalent. This technology aids in the early detection of plant diseases and pests, optimizing intervention processes for farmers. AI technology facilitates in-depth research on plant genetics and productivity. Moreover, the increasing use of AI in processes such as the storage and distribution of agricultural products could help reduce food waste and enhance food security. Furthermore, robotic technologies are also utilized in the agricultural sector. Robots, for instance, can replace agricultural workers in conducting harvesting operations, while robotic arms integrated into farming machinery perform tasks like plant harvesting, pruning, and spraying. These robotic technologies

enhance workforce efficiency in agriculture, reducing the workload for farmers (Sahin, 2022).

The agriculture industry can be managed more efficiently, sustainably, and intelligently with the assistance of artificial intelligence technology. Artificial intelligence is employed across various domains within the agricultural sector. For instance, an approach known as "precision farming" optimizes agricultural processes by collecting and analyzing field data through sensors and unmanned aerial vehicles (drones). Additionally, the use of AI in areas like weather forecasting, irrigation management, and soil analysis is increasingly prevalent. This technology aids in the early detection of plant diseases and pests, optimizing intervention processes for farmers. AI technology facilitates in-depth research on plant genetics and productivity. Moreover, the increasing use of AI in processes such as the storage and distribution of agricultural products could help reduce food waste and enhance food security. Furthermore, robotic technologies are also utilized in the agricultural sector. Robots, for instance, can replace agricultural workers in conducting harvesting operations, while robotic arms integrated into farming machinery perform tasks like plant harvesting, pruning, and spraying. These robotic technologies enhance workforce efficiency in agriculture, reducing the workload for farmers (Tarlasera, 2023; tarlaio, 2023;Celikten,2020).

Artificial intelligence can be utilized across various fields within the agricultural sector. One of these domains, known as "precision farming," improves agricultural processes by collecting and analyzing field data through sensors and unmanned aerial vehicles (drones). Moreover, the use of AI in areas such as weather forecasting, irrigation management, and soil analysis is increasing. AI contributes to the early detection of plant diseases and pests in agriculture, enhancing intervention processes for farmers. AI technology enables more extensive studies on plant genetics and productivity. Additionally, the use of artificial intelligence in processes like the storage and distribution of agricultural products may increase, aiding in reducing food waste and enhancing food security (*TÜBİTAK Bilim Genç, 2023;* Tarlaio, 2023).

As a part of smart agriculture, various technologies are involved, including sensors, remote sensing drones, satellite technologies, artificial intelligence, robot technologies, and image processing technologies. Sensors enable the measurement of soil and air temperatures, aiding in more informed and accurate practices like irrigation and pesticide application. Robots can take over tasks from agricultural workers, conducting harvesting operations, while robotic arms integrated into agricultural machinery can perform tasks such as plant harvesting, pruning, and spraying. Artificial intelligence has extensive applications in the agricultural sector. The method known as precision farming involves the collection and analysis of field data through sensors and drones to optimize agricultural processes. Additionally, the use of AI in areas like weather forecasting, irrigation management, and soil analysis is increasing. AI facilitates the early detection of agricultural issues, such as plant diseases and pests, optimizing intervention processes for farmers. AI technology allows for more comprehensive studies on plant genetics and productivity and has increasing potential for use in processes such as the storage and distribution of agricultural products. This potential can aid in reducing food waste and improving food security (Asgen Agriculture, 2021).

Digital agriculture

Digital agriculture refers to the tools that collect, store, analyze, and transmit electronic data and information throughout agricultural processes. These data are gathered sometimes through sensors and other times via cutting-edge technologies such as

satellites and drones. Digital agriculture is a comprehensive concept that, leveraging technological capabilities, provides real-time information to farmers on aspects like planting and harvesting timing, dynamic agricultural processes, weather forecasts, soil quality, required labor, and costs (Argenova, 2022; Imecemobil, 2021).

Advantages of digital agriculture

Digital agriculture encompasses tools that electronically collect, store, analyze, and deliver data or information throughout the agricultural cycle. Information is gathered through sensors or modern technologies like satellites and drones. It's a broad concept that provides real-time information to farmers regarding timing of planting and harvesting, dynamic agricultural processes, weather forecasts, soil quality, required labor, and costs through technological means. The benefits of digital agriculture include the following (Argenova, 2022; Asgen Agriculture, 2023; Imecemobil, 2021).

1. Increased Productivity: Digital agriculture enables farmers to achieve higher yields by better understanding soil and weather conditions through data analysis, thus increasing the likelihood of planting and harvesting the right crops at the right time (Asgen Agriculture, 2023).
2. Sustainability: Digital agriculture can aid in more efficient resource utilization, reducing unnecessary use of resources like pesticides, water, and fertilizers, minimizing environmental impact (Asgen Agriculture, 2023).
3. Disease and Pest Management: Early detection of plant diseases and pests using sensors and cameras allows for more effective control methods (Asgen Agriculture, 2023).
4. Marketing and Trade: Digital agriculture streamlines the marketing and distribution of products, enabling farmers to respond to demands more swiftly and reach broader markets (Asgen Agriculture, 2023).
5. Work Safety and Comfort: Automation and autonomous machinery can enhance farmer safety and ease the burden of laborious tasks (Asgen Agriculture, 2023)."

Technologies in digital agriculture

Among the technologies that support digital farming are tools such as sensors, satellite data, data analysis, Internet of Things (IoT), and Machine Learning. These smart technologies aid in enhancing productivity in agricultural fields, conducting soil analysis, monitoring plant health, utilizing smart irrigation methods, managing fertilizers, and detecting pests and diseases. Digital farming refers to the tools that electronically collect, store, analyze, and transmit data or information throughout the agricultural process. This farming method, using technological capabilities, provides farmers with real-time information in advance regarding the timing of planting and harvesting in fields, dynamic agricultural processes, weather forecasts, soil quality, required workforce, and costs. Digital farming applications benefit from technologies such as sensors, satellite data, data analysis, Internet of Things (IoT), and Machine Learning. These intelligent technologies can be used to enhance productivity in agricultural settings, perform soil analysis, monitor plant health, employ smart irrigation techniques, manage fertilizers, and identify pests and diseases (Argenova, 2022; Imecemobil, 2022).

The modern agricultural systems, also known as digital farming, constitute a vast field where drones and advanced innovations are integrated into a single system to offer farmers and other stakeholders the opportunity to enhance their production in agriculture. It provides a platform for producers to make more informed decisions about agricultural enterprise systems. Smart agriculture 4.0 also involves Decision Support Systems (DDS) that promote the optimization of inputs for the entire farm, facilitating

optimal use and conservation of resources needed for reduction, thereby encouraging target optimization. DDS can be utilized in almost every stage of operations related to management and administration, typically serving middle and upper-level management, aiming to extract valuable data from uncertain information primarily at the decision-making stage (Jayaraman, et al., 2016).

Agriculture 4.0 is defined as a system comprised of drones, robotics, vertical farming, artificial intelligence, the internet, and solar energy. The development of Agriculture 4.0 is based on the challenges of meeting the needs of the world's population with adequate food production (Jones & Pimdee, 2017). While Agriculture 4.0 applications often remain a barrier in developing countries, they are currently viewed as a solution to ongoing environmental, economic, and social issues (Yahya, 2018). Through smart agriculture, farmers will minimize the use of water, fertilizers, or agricultural chemicals, strengthening economies of scale and increasing profits across various farms, leading to lesser damage. According to significant reports related to Agriculture 4.0, farms and companies will be operated using advanced technologies such as sensors, devices, and machines. Most importantly, sophisticated technologies will be employed in the future to monitor soil moisture levels and temperatures in agriculture (Weltzien, 2016). It is anticipated that Agriculture 4.0 will enhance the high technology in agriculture and, thereby, promote the success of sustainable crop production (Kuo, 2015).

Ways of using sensors in agriculture

Sensors are utilized in agriculture for various purposes. For instance, pH sensors help enhance crop productivity by measuring nutrient levels in the soil. Temperature and humidity sensors play a role in creating an optimal environment for healthy plant growth. Additionally, these sensors can be employed in the storage process of agricultural produce. GPS sensors are used to track the locations of animals, enabling more effective monitoring of their health status. Agricultural sensors can effectively contribute to different areas such as improving productivity, conducting soil analysis, observing plant health, utilizing smart irrigation systems, managing fertilizers, and detecting pests and diseases in agricultural fields (Agriculture sensors,2020; Sensors in agriculture,2021; Steeneken, P.G., Kaiser, E., Verbiest, G.J. et al.,2023).

Autonomous Systems in Agriculture and Their Importance

Autonomous technologies in the agricultural sector are systems used to automate agricultural machinery and processes. These systems enable automatic operation of farming machinery, reducing the workload for farmers and enhancing efficiency. For instance, autonomous tractors can replace human labor by performing harvesting tasks. Similarly, robotic arms integrated into agricultural machinery can conduct activities like crop harvesting, pruning, and pesticide application. Autonomous systems improve workforce efficiency in agriculture, lightening the load for farmers. Moreover, these systems enhance productivity in agriculture while aiding in the more effective utilization of resources, contributing as a factor for sustainability in the agricultural sector (World Economic Forum,2022;Koch,2023; Autonomous farm tractors,2021).

Technologies in Autonomous Agricultural Machinery

Autonomous agricultural machinery integrates various technologies within the agricultural sector. These technologies include artificial intelligence, image processing, sensors, radar sensors, laser scanners, GPS sensors, machine learning, and statistical data analysis. Autonomous agricultural machines are systems used to automate agricultural processes. These systems enable farming machinery to operate automatically, reducing the workload for farmers and enhancing efficiency. For instance, autonomous tractors can replace human labor by conducting harvesting tasks. Similarly, robotic arms integrated into agricultural machinery can perform activities like crop harvesting,

pruning, and pesticide application (World Economic Forum,2022; Koch,2023; *T.C. Trakya University,2022; Autonomous farm tractors*,2021).

Studies on Artificial Intelligence Applications in Agriculture

Artificial intelligence technology is extensively utilized across various domains within the agricultural sector. These encompass sensors, cameras, robots, and other devices generating large sets of data. These technologies find frequent use in feed mixing machines, milking robots, temperature and humidity measurements, feed and water consumption, facial recognition, environmental air control, determination of sleep cycles, live weight estimations, heat tracking, behavioral analysis of animals, and emotional contagion. Artificial intelligence is initiating a new era in food production within the agricultural sector, bringing about revolutionary changes. From better resource utilization to disease monitoring and weather forecasting, artificial intelligence provides powerful tools to enhance productivity, reduce environmental impact, and improve sustainability for farmers. In agriculture, artificial intelligence optimizes precision farming, enabling early detection of plant diseases and pests, thereby refining intervention processes for farmers. Furthermore, the technology facilitates broader research on plant genetics and efficiency. By enabling the early detection of agricultural issues such as plant diseases and pests, AI enhances intervention processes for farmers (Tanya,2023).

The Advantages of Utilizing Artificial Intelligence and Robotic Technologies in Agriculture

The use of artificial intelligence and robotic technologies in the agricultural sector offers numerous benefits. Artificial intelligence assists farmers in making more precise and faster decisions in areas such as data analysis, prediction, and automation within agriculture. Additionally, it enables more efficient utilization of resources while increasing agricultural production. By contributing to the early detection of problems like plant diseases and pests, AI optimizes intervention processes for farmers. Robotic technologies, on the other hand, are employed for automating agricultural processes. These systems, through the automatic operation of agricultural machinery, alleviate the workload of farmers and enhance productivity. For instance, autonomous tractors replace human labor by conducting harvesting operations. Similarly, robotic arms integrated into agricultural machinery can perform tasks such as crop harvesting, pruning, and pesticide application. (World Economic Forum,2022;Hektaş, 2022).

Artificial intelligence (AI) and robotic technologies have the potential to enhance productivity and efficiency at every stage of the agricultural value chain, increase farmers' incomes, reduce waste while boosting farm efficiency, and enhance supply chain efficiency, transparency, and sustainable resource utilization. AI can analyze market demand, predict prices, and determine the optimal times for planting and harvesting. In agriculture, AI can assist in gathering insights, monitoring weather conditions, and recommending fertilizer and pesticide applications to explore soil health. The use of AI in agriculture can also aid in identifying diseases in plants, recognizing crop diseases and pest damage, and identifying a disease with 98% accuracy. Robotic technologies, such as autonomous tractors and robotic arms mounted on agricultural equipment, can automate tasks such as planting, harvesting, pruning, and pesticide application, reducing labor costs and increasing efficiency (World Economic Forum,2022; Soffar, 2019).

Agriculture 4.0 Core Technologies:

In the agricultural sector, while data utilization boasts a long history, the innovation driving the sector's digital evolution primarily resides in this domain. Additionally, the quality of information gathered at the farm level and the technologies employed to collect, store, process, manage, and distribute such data are noteworthy. Advancements in sensor

technology enable farmers to monitor specific measurements in real-time, facilitating more efficient automation of robotic processes. Furthermore, computing power has become increasingly accessible and cost-effective, thereby aiding the development of new decision support tools to enhance agricultural management.

a) Sensors

Sensors stand as one of the primary driving forces behind the IoT concept due to advancements in technologies that not only shrink their size but also make them smarter and more affordable (Ur Rehman, Abbasi, Islam, & Shaikh, 2014; Kassim & Harun, 2016). In recent years, wired and wireless sensors have been extensively utilized within the agricultural sector (Tzounis, Katsoulas, Bartzanas, & Kittas, 2017). By acquiring plant, animal, and environmental data, sensors play an indispensable role in agricultural activities, forming a crucial technology for IoT implementation in agriculture. Spatial and temporal variations that significantly impact agricultural production can generally be managed through two approaches: map-based and sensor-based methods (Zhan, Wang, & Wang, 2002). Both approaches involve stationary or mobile sensors and necessitate extensive big data collection and analysis to more efficiently utilize farm inputs, thereby leading to enhanced crop production and environmental sustainability (Mulla, 2013).

b) Robotics

Robots' application in automating certain tasks in this sector, such as product monitoring (plant monitoring and phenotyping), planting and harvesting, water supply, targeted spraying, environmental monitoring, has increased the interest in agriculture in recent years (Fountas, Mylonas, Malounas, Rodias, Hellmann Santos, & Pekkeriet, 2020; Shamshiri, Weltzien, Hameed, Yule, Grift, Balasundram, Pitonakova, Ahmad, & Chowdhary, 2018 Roldán, del Cerro, Garzón-Ramos, Garcia-Aunon, Garzón, de León, Barrientos, 2018). Tasks like weed and pest control, disease detection, pruning, milking, and sorting are also within the realm of robotic science. While mentioning UAVs and drones in the context of remote sensing, it's important to emphasize their direct applicability in fields, performing specific agricultural tasks. Fixed robots are typically more prevalent in industrial applications; however, in the agricultural context, mobile robots can offer greater benefits. Their ability to traverse various terrain types under different landscape conditions inaccessible to ground vehicles, cover large areas, and automate agricultural tasks holds significant potential for advancing agricultural management. Figure 3 highlights UAVs' frequent mention in various agricultural applications such as yield estimation (Apolo-Apolo, Martínez-Guanter, Egea, Raja, & Pérez-Ruiz, 2020), product disease detection (Chung, Huang, Chen, Lai, Chen, & Kuo, 2016), weed recognition and mapping (Pantazi, Tamouridou, Alexandridis, Lagopodi, Kashefi, & Moshou, 2017). Additionally, UAV-integrated systems can be contemplated as a safety system for worker health, preventing health issues arising from the manual spraying of agricultural chemicals in fields (Mogili, Deepak, & B,2018). Another variant of mobile robots extensively used in the agricultural sector in recent years is UGV, designed primarily to enhance agricultural efficiency and reduce manual labor, particularly in challenging environments for humans to access. These robots participate in various agricultural tasks like field processing, soil sampling, irrigation management, precise spraying, mechanical weed clearing, and crop harvesting (Bonadies, Lefcourt, & Gadsden, 2016; Arad, et al., 2020).

c) Internet of Things

IoT fundamentally represents the interlinking of physical and digital entities through standardized and compatible communication protocols (Shi, An, Zhao, Liu, Xia, Sun, Guo, 2019). Its integration spans across diverse sectors like healthcare, smart residences, urban development, and industrial manufacturing. Considering the imperative need for continual oversight and management of farming operations, the integration of IoT solutions into agriculture stands as a pivotal necessity (Shi, An, Zhao, Liu, Xia,

Sun, & Guo, 2019; Farooq, Riaz, Abid, Umer, & Zikria, 2020). The convergence of different Agriculture 4.0 technologies with IoT manifests immense potential, promising amplified efficacy in agricultural practices, each demanding distinct prerequisites. In agricultural discourse within the realm of IoT, a spectrum of communication protocols and technologies has been deployed to align with these requisites.

d) Cloud Computing

Commercially internet-based infrastructure, known as cloud computing, has risen to prominence by delivering hardware, infrastructure, platform, software, and storage services for a range of contemporary IoT applications. Over the last decade, cloud computing has captured considerable attention within the agricultural domain, providing (Shi, An, Zhao, Liu, Xia, Sun, & Guo, 2019): (a) economical data storage services accommodating textual, visual, video, and other agricultural data, substantially trimming storage expenses for agricultural entities; (b) sophisticated large-scale computing systems capable of converting raw data (often challenging for farmers to adeptly utilize due to technical complexities) into actionable insights, facilitating data-centric decision-making; and (c) a secure platform empowering farmers and nurturing the proliferation of diverse IoT applications tailored for agricultural purposes.

e Data Analytics

e.1. Big Data (Analytics)

The advent of IoT technologies facilitated comprehensive data acquisition across every facet of the agricultural supply chain, resulting in the generation of increasingly vast datasets. However, the agricultural sector's utilization of this data remains relatively limited (Wolfert, Ge, Verdouw, & Bogaardt, 2017; Kamilaris, Kartakoullis, & Prenafeta-Boldú, 2017), overlooking a substantial opportunity for groundbreaking, data-centric innovations aimed at fostering more efficient and sustainable production and consumption practices in the long run. Within this context, big data analytics holds a pivotal role in translating data into value for agricultural and food stakeholders by efficiently collecting, processing, and visualizing extensive and intricate datasets. Literature often defines big data across five dimensions (Demchenko, Grosso, De Laat, & Membrey, 2013): volume, velocity, variety, value, and veracity. Recent studies suggest that although big data is still nascent, its impact on the landscape and structure of Agriculture 4.0 will be profound. Leveraging high-volume, multi-source real-time, and historical data for analysis, prediction, and monitoring is expected to significantly revolutionize farm management and operations, continually enhancing business models. Beyond conventional applications such as optimizing production efficiency using large historical and multi-domain datasets (e.g., temperature, precipitation) (Majumdar, Naraseeyappa, & Ankalaki, 2017), big data analytics opens avenues to address more intricate and less prevalent scenarios. For instance, it enables forecasting food availability in developing nations to tackle sustainable food security challenges, achieved through the analysis of land use and production data collected from over 13,000 farm households across 17 countries in Sub-Saharan Africa.

e.2. Artificial Intelligence and Machine Learning

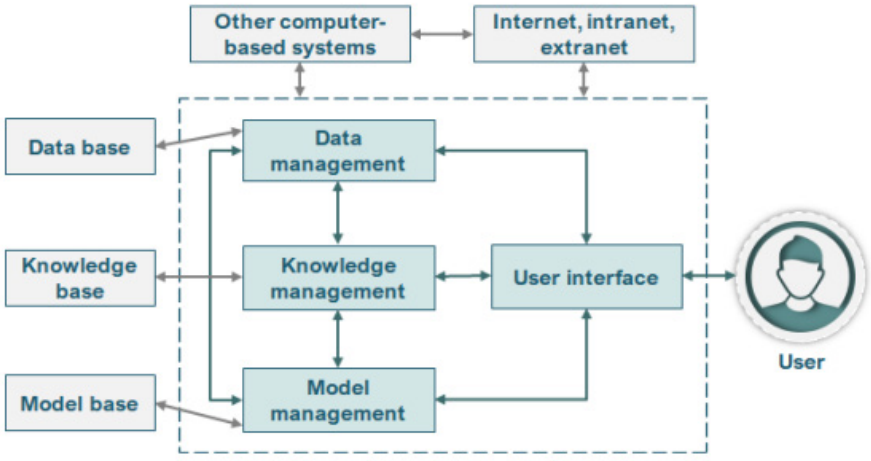
Artificial Intelligence, particularly its Machine Learning facet, in conjunction with Cloud Computing and IoT, stands out as a pivotal catalyst driving the implementation of Agriculture 4.0. Recent research underscores that ML emerges as among the most auspicious techniques presently under exploration in domains such as food security, weed control, soil, crop, and livestock monitoring, as well as weather forecasting and climate shifts (Liu, Ma, Shu, Hancke, & Abu-Mahfouz, 2020; Wolfert, Ge, Verdouw, & Bogaardt, 2017; Kamilaris, Kartakoullis, & Prenafeta-Boldú, 2017). ML algorithms have been harnessed to optimize crop yield, reduce input costs by discerning intricate patterns and correlations within multidimensional, diverse agricultural data, furnish

accurate predictions, and establish a robust framework for elevated agricultural decision-making and operational oversight (Shi, An, Zhao, Liu, Xia, Sun, & Guo, 2019). An updated compilation highlights that 61% of agricultural articles using ML approaches have concentrated on crop management, 19% on livestock, 10% on soil, and 10% on water management. Among the prevalent ML algorithms in the context of Agriculture 4.0 are random forests, SVMs, ANNs, and various DL iterations, notably CNNs for computer vision applications, as delineated in Figures 2 and 3. However, given the novel challenges posed by the imperative to devise scalable solutions within Agriculture 4.0, novel methodologies are emerging within the scientific community to address cybersecurity and privacy concerns in the digital era, including federated learning and privacy-preserving mechanisms. These strategies pivot on collaboratively deploying ML models across multiple nodes sans sharing sensitive private data samples, constraining the training process to local parameters exclusively (Xu, Li, Liu, Yang, & Lin, 2019). This effectively mitigates the aforementioned security and scalability apprehensions, paving a promising research path for AI within the ambit of Agriculture 4.0.

f) Decision Support System

The concept of a Decision Support System doesn't rely on consent, but within this study's framework, a DSS represents software designed to streamline the utilization of intricate data, aiding end-users in making informed decisions efficiently. This entails converting both raw data and analytical tool outcomes into understandable information displayed through a user-friendly interface. Concerning the architecture of a DSS, Figure 1 illustrates a standard structure based on the architectural model proposed by Turban and associates (Turban, 2007).

Figure 1. *A decision support system typically comprises four fundamental elements: data aggregation, model development, knowledge organization, and user interface design.(Turban, 2007).*



In the Agriculture 4.0 paradigm, there is a flow of information among core technologies. Five significant stages have been identified: sensor and robotic technology encompassing sensing and application functions based on system requirements, the Internet of Things for data communication, cloud computing for data storage and processing, data analytics involving methods based on big data and artificial intelligence, and decision support systems for data visualization, recommendation functions, and user interaction.

Artificial intelligence applications stand as one of the most critical research areas in agriculture today and in the near future, offering potential solutions to streamline agricultural processes and develop alternative solutions for outstanding challenges.

The use of AI techniques in agriculture spans various domains such as crop production planning, plant classification, yield prediction, identification of plant diseases, pests, and weeds. Additionally, researchers have conducted numerous studies in determining routes for agricultural robots, making application decisions, defining greenhouse conditions, forming operational strategies, managing irrigation, crop rotation, and selecting fertilizers and machinery. Examples of AI research conducted in agriculture are provided in Table 1.

Table 1. *Examples of agricultural studies conducted using artificial intelligence techniques (Terzi, Özgüven, Altaş, & Uygun, 2019).*

Artificial Intelligence Techniques	Research Topics	Studies Conducted
Fuzzy Logic	Irrigation management Detection of water resources Determination of agricultural potential Decision support system in production Greenhouse systems	(Martha et al., 2016); (Faridi et al., 2018); (Kurniasih et al., 2018); (Kale and Patil, 2018); (Ali et al., 2018)
Artificial Neural Networks	Energy consumption in production Disease classification Production management Agricultural waste processing	(Khoshnevisan et al., 2015); (Oppenheim and Shani, 2017); (Kamilaris & Prenafeta, 2018); (Liu et al., 2018); (Khoshroo et al., 2018)
Genetic Algorithms	Drying process for products Land use optimization Prediction of soil mechanical resistance Automatic land classification Disease detection	(Khawas et al., 2015); (Li and Parrott, 2016); (Hosseini et al., 2016); (Haklı ve Uğuz, 2017); (Arya et al., 2018)
Expert Systems	Weed detection Identification of greenery Condition monitoring in agricultural machinery System analysis in animal production Land allocation	(Montalvo et al., 2013); (Romeo et al., 2013); (Martinez et al., 2015); (Vasquez et al., 2018); (Haklı ve ark., 2018)
Ant Algorithms	Planning agricultural contracting work Irrigation management Disease detection and classification Soil nitrogen content estimation	(Alaiso et al., 2013); (Nguyen et al., 2017); (Zhang et al., 2018); (Zhang et al., 2019)

Consequence

Ensuring economic, sustainable, and efficient agricultural production is the primary aim in agriculture. Each advancement contributes to various developments or has a facilitating effect on its own. The latest leap, Society 5.0, focuses on leveraging more effectively the impactful components such as cyber-physical systems, autonomous robots, artificial intelligence, 3D printers, cloud computing, and more offered by Industry 4.0. The goal here is to use new technologies considering the interests of society, improving living conditions, fostering social development, and achieving sustainable levels of well-being. This study aims to delve into the intersection of robotics, artificial intelligence, and agriculture, addressing the robotic tools and AI applications used in the agricultural sector. The research entails an extensive literature review on AI and robotic studies in agriculture. The utilization of robots and AI in agriculture offers advantages such as saving space and labor while enhancing quality production. Developments tied to Industry 4.0 will significantly contribute to the agricultural field. It's recommended to increase efforts in robotics applications and AI-related studies within the agricultural sector.

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