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ARTIFICIAL INTELLIGENCE (AI): ITS ROLE IN AGRICULTURE

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ABSTRACT

Artificial intelligence is the ability of computer or a robot operated by a computer to do tasks that are usually drone by human beings because they require human intelligence and discernment. It is used in several applications, such as image detection, natural language processing and predictive analytics. In agriculture, machine learning algorithms can be used to analyse data from sensors and drones to predict crop yields, identify diseases or pests, optimize irrigation and fertilization. Machine learning can also be used in precision farming to create personalized treatment plans for individual plants based on their unique characteristics and requirements. Overall, AI has the potential to significantly enhance the efficiency and productivity of agriculture, while reducing costs and environmental impact.

Key words : Artificial intelligence, Robotics, Machine learning.

Introduction

Artificial: The term artificial is defined as made or produced by human beings rather than occurring naturally, especially as a copy of something natural

Artificial Intelligence : Artificial Intelligence refers to the simulation of human intelligence in machines that are programmed to think like humans and to mimic their action. The theory and development of computer systems able to perform tasks normally requiring human intelligence such as visual perception, speech detection, decision making and translation between languages. Artificial intelligence makes it possible for machines learn from experience and adjust to new input and perform human like task.

Types of Artificial Intelligence

- **Artificial Narrow Intelligence (ANI):** Artificial Narrow Intelligence (ANI) refers to a type of AI that is outlined to perform specific tasks or solve particular complications within a limited domain. ANI systems are programmed to perform a single task or a set of related tasks, and they can do so with high accuracy and speed (Fjelland, 2020). Examples of ANI include voice recognition software, image recognition algorithms, and chatbots. ANI systems are not capable of generalizing knowledge or learning from experience outside of their domain, and they cannot adapt to new situations without being reprogrammed. ANI is also known as Weak Artificial Intelligence. E.g.: Alexa, Siri, Sofia, Self-driving cars.
- **Artificial General Intelligence (AGI) :** Artificial General Intelligence refers to a type of AI that has the capability to understand or learn any intellectual task that a human being can. AGI systems are designed to be capable of reasoning, problem-solving and decision-making across multiple domains. They can learn from experience and adapt to new context without being explicitly programmed. AGI is often considered the ultimate gaol of AI research as it would enable machines to perform any intellectual task that humans can (Goertzel, 2014). However, AGI remains a theoretical concept and no system has yet achieved this level of intelligence. AGI is also known as Strong AI. *e.g:* No system has yet achieved this intensity of intelligence but that are considered a step towards AGI are OpenAI's GPT-3 language model, Google's

AlphaGo and IBM's Watson.

- **Artificial Super Intelligence (ASI) :** Artificial Super Intelligence (ASI) is a theoretical concept that refers to an AI system that surpasses human intelligence in all areas. This type of AI would be able to solve complex problems, make decisions and create new knowledge at a level that far exceeds human capabilities. There are no examples of ASI as it remains a hypothetical concept that has not yet been achieved (Gill, 2016). However, some experts believe that it could be possible in the future of AI continues to develop at an exponential rate. The development of ASI elevates important ethical and existential questions about the potential impact on society and humanity as a whole.

Artificial Intelligence technologies

- **Robotics :** Robotics is a field of engineering and science that deals with the design, construction, operation, and manoeuvre of robots. It involves the integration of various technologies such as mechanical engineering, electrical engineering, computer science, and artificial intelligence (AI). AI is a branch of computer science that deals with the development of intelligent machines that can perform tasks that typically require human intelligence, such as visual perception, speech recognition, decision-making, and language translation (Sarker, 2022). In robotics, AI technology is used to enable robots to execute complex tasks autonomously or with minimal human intervention. For example, robots equipped with AI can learn from their environment and adapt their behaviour accordingly. They can also perceive their surroundings using sensors and cameras, process information using algorithms and machine learning techniques, and make decisions based on that information. Moreover, AI technology in robotics allows robots to interact with humans in a more natural and innate way. For instance, robots can understand human speech and respond appropriately, recognize facial expressions and gestures, and even learn to anticipate human behaviour (Kerstein, 2007). As a result, AI-enabled robots have the potential to revolutionize various industries, including manufacturing, healthcare, transportation and agriculture.
- **Natural language processing :** Natural Language Processing (NLP) is a subfield of artificial intelligence (AI) that focuses on the relation between computers and human language. It involves the use of algorithms and computational models to enable computers to understand, interpret, and generate human language (Baclic *et al.*, 2020). NLP technology is used in numerous applications, such as language translation, sentiment analysis, speech recognition, chatbots and text outline. For instance, NLP algorithms can analyse large volumes of text data and extract useful insights from it, such as identifying patterns, trends and sentiment.
- **Pattern recognition :** Pattern recognition is the ability of a machine or human to identify patterns in data and make predictions based on those patterns. In the context of artificial intelligence (AI), pattern recognition involves using algorithms and statistical models to analyse large datasets and identify patterns or trends that can be used to make predictions or decisions (Duin *et al.*, 2007). For example, in image recognition, a machine learning algorithm can be trained on a large dataset of images to recognize specific patterns, such as the features of a face or the shape of an object. Once the algorithm has learned these patterns, it can then be used to identify similar patterns in new images.
- **Machine Learning :** Machine learning is a subset of artificial intelligence (AI) that involves training algorithms to make predictions or decisions based on figures. It involves using statistical models and algorithms to analyse and learn from large datasets, without being categorically programmed to do so. In machine learning, the algorithm is provided with a set of input data and a desired output or prediction, and it uses this data to learn and improve its accuracy over time (Sarker, 2022). The algorithm adjusts its parameters based on the patterns it identifies in the data, allowing it to make more accurate predictions or decisions in the future.

Artificial Intelligence in Agriculture : Agriculture sector have benefited from incorporation of technological advances. Several methodologies require high energy input. Agriculture is lacking the system or solution for chronic problems. The application of the AI in agricultural activities will highly increase the productivity, sustainability, transportation activities etc. Artificial intelligence (AI) in agriculture involves the use of advanced technologies and algorithms to improve farming practices and increase crop yields. AI can be used in various areas of agriculture, such as crop monitoring, soil analysis, and irrigation management. One application of AI in agriculture is precision farming, which involves the use of sensors and data analytics to optimize crop growth and to manage waste (Talaviya, 2020). For example, AI can analyse data from sensors that monitor soil moisture variations, temperature and other environmental factors to determine the optimal conditions to plant, water, and harvest crops. Another application of AI in agriculture is crop disease detection. Machine learning algorithms can analyse images of crops to identify symptoms of disease or pests, allowing farmers to take precaution before the problem spreads and reduces crop yields. AI can also be used to improve livestock management. For example, sensors can be planted on animals to monitor their health and behaviour, allowing farmers to detect signs of illness or stress early and provide appropriate care. Overall, AI has the potential to revolutionize agriculture by increasing efficiency, reducing waste, and improving sustainability. As the world population continues to grow, the use of AI in agriculture will become increasingly important in ensuring food security for all.

Advantages of Artificial Intelligence : Artificial Intelligence helps in practising precision agriculture playing important role in Crop monitoring, Increasing input efficiency, Improves crop yield, Enhancing sustainability, Disease detecting and prevention, Livestock management, Cost savings, Improves food security etc.

Sensor based technologies and artificial intelligence systems used in Agriculture

Global Positioning System (GPS) : Global Positioning System (GPS) is a satellite-based navigation system that allows users to determine their precise location and track movements in real-time (Abulude *et al.*, 2015). In agriculture, GPS technology is used to improve precision farming techniques by enabling farmers to map their fields, monitor crop growth and optimize resource use.

Mobile devices : Mobile devices such as smartphones and tablets are increasingly being used in agriculture to improve communication, data collection, and decision making.

Precision irrigation : Precision irrigation is a method of watering crops that utilizes technology to deliver water precisely where and when it is needed. This approach involves the use of sensors, mobile devices, and other tools to monitor soil moisture content, weather conditions, and other factors that affect plant growth and water requirements (Violino *et al.*, 2023). By collecting and analysing data in real-time, farmers can adjust their irrigation schedules to ensure that crops receive the optimal amount of water for their growth stage and environmental conditions. This helps in improving water management, improve crop yields and quality, and promote sustainable agriculture practices.

Sensors : Sensors in agriculture are electronic devices that are used to collect data about various environmental factors such as soil water content, temperature, humidity, light and nutrient levels. These sensors are placed in the soil or on plants to monitor their growth and health. The data collected by these sensors is then transmitted to a central computer or mobile device, where it is analysed and used to make decisions about irrigation, fertilization and other farming practices (Rajak *et al.*, 2023). Sensors can help farmers optimize their crop yields, increase water use efficiency and minimize the use of fertilizers and pesticides. They are an important tool for precision agriculture, which aims to improve the efficiency and sustainability of farming practices.

The Internet of Things (IoT) : IoT in agriculture refers to the use of connected devices and sensors to collect and transmit data about various aspects of farming operations. This includes data on soil moisture, temperature, humidity, light, and nutrient levels, as well as information on equipment usage and livestock behaviour (Rajak *et al.*, 2023). The data collected by these devices is then analysed to provide insights into crop health, yield potential and other factors that can impact farming operations.

Variable rate of technology : VRT is the practice of adjusting inputs such as water, fertilizer, and pesticides based on the specific needs of different areas within a field. This is done by using data collected from sensors and devices to create detailed maps of soil and crop conditions (Griffin *et al.*, 2020). Farmers can then use this information to apply inputs precisely where they are needed, reducing waste and increasing efficiency

Weather Modelling : Weather modelling in agriculture involves using technology to collect and analyse weather data to create predictive models that help farmers make informed decisions about their farming operations (Hachimi *et al.*, 2023). This includes collecting data from weather sensors and devices, as well as other sources such as satellite imagery and historical weather patterns.

Nitrogen Modelling : Nitrogen modelling in agriculture involves using technology to collect and analyse data on nitrogen levels in soil and crops to create predictive models that help farmers make informed decisions about their fertilizer application (Silva *et al.*, 2023). This includes collecting data from soil sensors, crop sensors, and other sources such as satellite imagery and historical nitrogen patterns.

Application of AI in Agriculture

Tillage and Sowing : AI is being increasingly used in tillage and sowing to improve efficiency and reduce waste. AI algorithms can analyse data on soil moisture, temperature, and nutrient levels to determine the optimal time and method for tilling and sowing, *e.g.*, AI powered tillage machines, AI- powered seeders and decision support systems such as FloDSS (Fuzzy logic-based decision support system), SOWING APP (ICRISAT), Hands Free Hectare (HFH) etc.

Nutrient management : AI can forecast crop nutrient requirements based on historical data, environmental conditions and crop growth stages. These predictions enable farmers to plan nutrient application in advance, ensuring that plants receive the necessary nutrient at each growth stage. This significant approach reduces the risk of nutrient deficiencies or nutrient excess. Helps in analysing the nutrient composition of organic amendments such as FYM, compost and Manure. Use of AI in improves the adoption of sustainable practices, decreases reliance on chemical, synthetic fertilizers and reduces the environmental pollution *e.g.*, Nutrient Expert, Green Seeker, Auto FERT.

Abayomi-Alli *et al.* (2019) reported that a decision support system called Auto FERT for automatic crop fertilization using bag of visual words (BoWs) technique was developed to assist in automatic fertilization recommendation for deficient plants through leaf symptoms. Auto FERT successfully obtained results from the experiments on 77 test images showed a classification accuracy of 97.4 per cent, 94.8 per cent, 96.1 per cent and 96.1 per cent for nitrogen, healthy, phosphorus and potassium deficient leaves, respectively.

Pooniya (2015) studied precision nutrient management technology with site-specificnutrient-management (SSNM) – Nutrient Expert (NE) guided by decision-support system software. Results indicated that system-productivity of wheat equivalent yield (WEY) with SSNM-NE + FYM @ 5 tonnes ha^{-1} and with 125 per cent recommended NPK was 38.8 (12.3%) and 36.8 (9.8%) higher over control, respectively (Fig. 1). SSNM-NE + FYM recorded highest available N, K and soil organic carbon (SOC) in 0-15 cm soil depth followed by 125 per cent RDF and SSNM treatments.

Experimental results showed that robotic system for nitrogen fertilizing management decreased the nitrogen fertilizer consumption about 18 per cent without lowering the fruit yield or fruit quality parameters including firmness (Fig. 2), total soluble solids, chlorophyll and ascorbic acid contents and considered as an efficient nitrogen fertilizing management method in commercial greenhouse using a low-cost machine vision based robotic system (Vakilian and Massah, 2017).

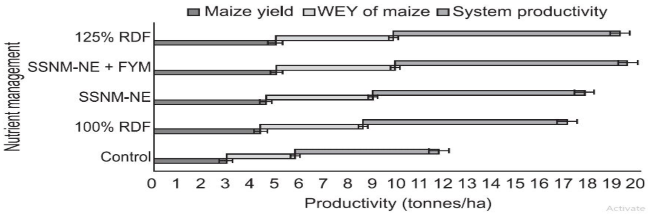

Fig. 1 : Influence of Nutrient-Expert assisted nutrient management on crop yields and system productivity of maize-wheat cropping system.

Weed management: Weed management by AI provides more efficient and accurate methods of weed control methods. AI can be used to develop image recognition systems that can identify weeds with a high degree of accuracy (Aashish, 2023). Drones, robots and autonomous vehicles helps in scanning the fields and identifying weeds and then apply herbicides to control. Artificial Intelligence also helps in predictive modelling and weed mapping; *e.g.*, 5G automation robots, Graphics Processing Units (TX2 GPU, GTX 1070 and Ti GPU) etc.

Sujaritha *et al.* (2017) reported that Weed detecting robotic prototype designed and developed using a Raspberry Pi micro controller and suitable input output subsystems such as cameras, small light sources and motors with power systems. Prototype’s control incorporates the weed detection mechanism using a Raspbian operating system support and python programming (Fig. 3). The designed robotic prototype correctly identifies the sugarcane crop among nine different weed species and the system detects weeds with 92.9 per cent accuracy over a processing time of 0.02s.

Irrigation management: Artificial intelligence in irrigation systems use sensors to monitor soil moisture level and precise application of water to meet out the water requirement of crops. Helps in improving water efficiency, improve crop yields and reduces risk of crop failure due to drought or other environmental factors. AI in water management helps in understanding and analysing when a plant is stressed due to either scarce or excess water supply. Use of soil moisture sensors sense the area’s dryness and irrigate the land. It will irrigate the land only when the plant is thirsty (Renavikar *et al.*, 2021); *e.g.*, sensor based irrigation system, IoT based irrigation system.

Chaitra (2019) studied sensor and SMI based irrigation management in Maize to enhance growth, yield and water use efficiency and reported that sensor-based

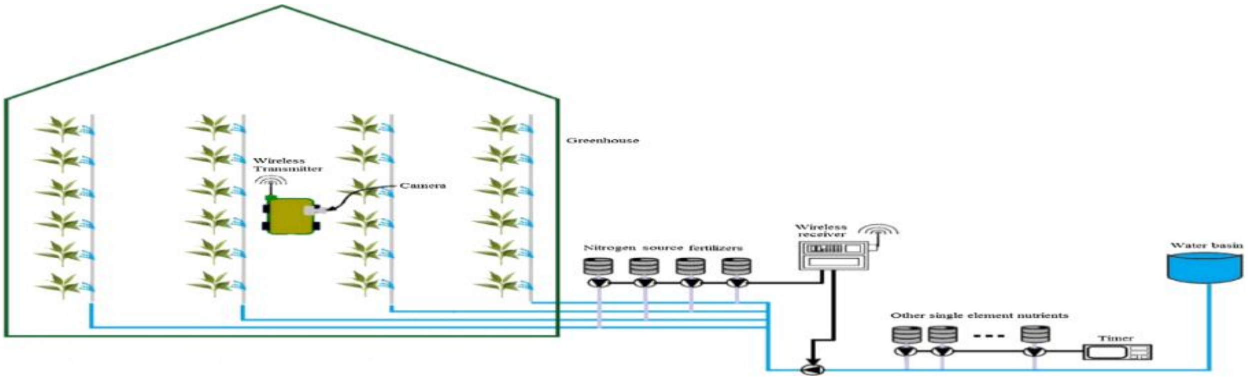

Fig. 2 : Schematic view of the proposed robotic system for nitrogen fertilising management.

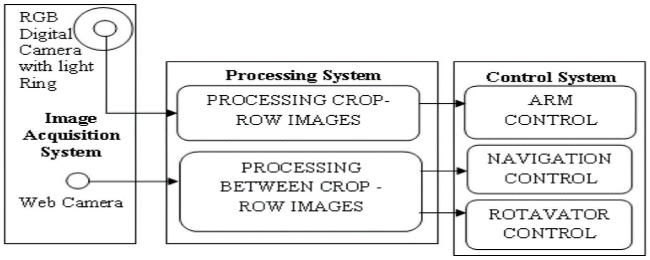

Fig. 3 : Architecture of the weeding robotic model.

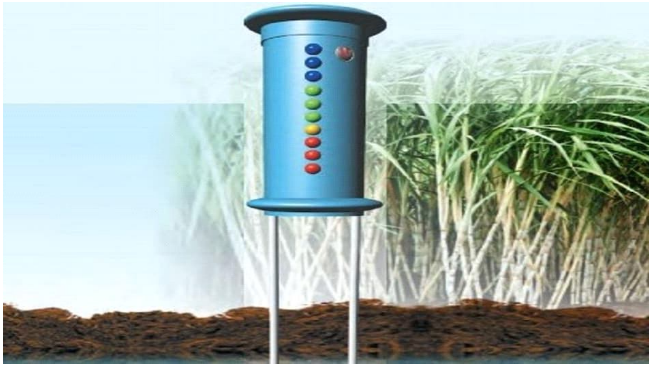

Fig. 4 : Soil Moisture Indicator.

drip irrigation at 25% DASM recorded significantly higher grain yield (10676 kg ha^{-1}), higher water use efficiency (219.2 kg ha-cm^{-1}). Whereas the lower grain yield (6551 kg ha^{-1}), water use efficiency (131.8 kg ha-cm^{-1}) was observed in surface irrigation (Fig. 4). The increase in the yield was due to availability of sufficient moisture in the soil which favoured photosynthetic production and translocation of photosynthates to the sink. Higher water use efficiency with the drip irrigation system was due to reduced water loss and efficient water use by the plants resulting in higher yield. Kim *et al*. (2008) developed an conceptual system layout of infield wireless sensor network for site-specific irrigation. In this, there is in-field sensing station which consists of sensors which measures soil moisture, soil temperature, air temperature, consists of bluetooth radio transmitter (Fig. 5). Sensed data will be sent to base station where analysis of data is done and in-turn transmitted to irrigation control station through micro-controllers. The data at the base station will be analyzed with the help of decision support systems (DSS).

Barkunan *et al*. (2019) proposed an automated drip irrigation system which consists of ARM microcontroller, smart phones, GSM module, sensor unit and motor control unit. The sensor unit comprises of temperature sensor, humidity sensor, light sensor and rain sensor (Fig. 6), which is used to monitor the environmental conditions by collecting the physical parameters such as temperature, humidity, light intensity and rainfall of the agriculture field the global system for mobile communication (GSM) module in the proposed irrigation system is used for sending and receiving the messages between microcontroller and smartphone.

Pest and Disease management: AI is used to improve pest and disease management in agriculture. By analysing data on weather patterns, soil health conditions, and crop growth, AI algorithms can predict the likelihood of pest and disease outbreaks and provide farmers with early warning alerts *e.g.*, Drones, Agrio app, Variable rate application (VRA) etc.

Tewari *et al*. (2020) studied chromatic aberration (CA) based image segmentation method to detect the diseased region of paddy plants, based on which the solenoid valves remained on for a specific time duration so that the required amount of agrochemical could be sprayed on the diseased paddy plants (Fig. 7). Field performance of developed sprayer prototype was evaluated in the variable-rate application (VRA) and constant-rate application modes (CRA) and reported that field testing results showed a minimum 33.88 per cent reduction in applied chemical, while operating in the VRA mode as compared with the CRA mode.

Harvesting: Artificial Intelligence in crop harvesting enables automated crop selection and accurate planting depth control. Advancements in autonoums vehicles technology fuel agricultural robotics growth. AI is also

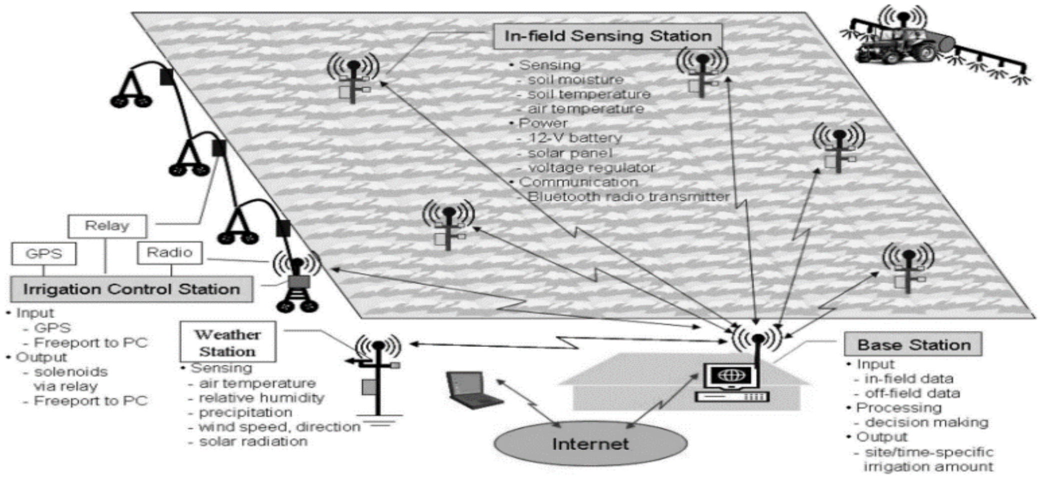

Fig. 5 : Conceptual system layout of in-field wireless sensor network for site -specific irrigation.

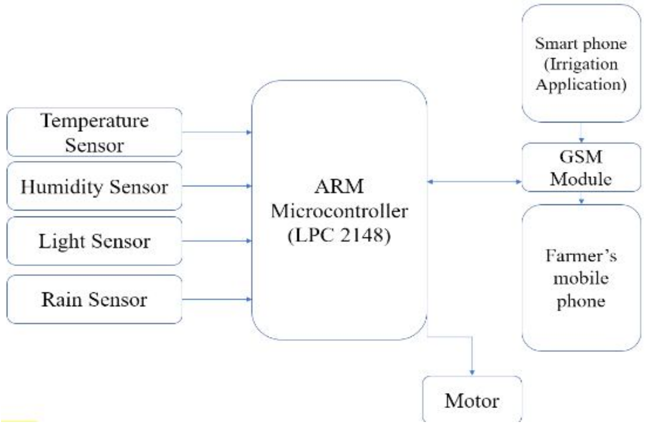

Fig. 6 : Block diagram of proposed smart sensor based irrigation system.

being used in the harvesting of crops to improve efficiency and reduce labour costs. Harvesting robots equipped with AI algorithms can identify ripe fruits and vegetables and pick them with precision, reducing waste and increasing yield. These robots can also work around the clock, allowing farmers to harvest their crops faster and more efficiently. AI algorithms can also help these robots navigate through fields and avoid obstacles, reducing the risk of damage to crops.

Xiong (2019) developed a low-cost dual-arm system optimizing harvesting sequence increasing its efficiency, minimising the risk of collision. Robots in first -attempt recorded 50 per cent to 97.1 per cent success rate of strawberry picking depending on the growth situations (Fig. 8).

AI in price forecasting of agricultural commodity: The agriculture commodity price forecast will play an important role for the farmers, the policymakers, and various administrative offices. For example, if a farmer knows in advance the price of crop in near future (short term), then he can decide about the farming area of that particular crop to be undertaken. Other than farmers, government agencies also need to know the probable price of commodity in advance for implementing government schemes (subsidy schemes and import/export activity) smoothly. Agriculture commodity forecasting is very important for sustainability of future generations. With ever increasing demand of agricultural products and reduction in agricultural land, this forecasting methodology is very important for sustainability of farmers (Mahto *et al.*, 2021). There are many traditional/

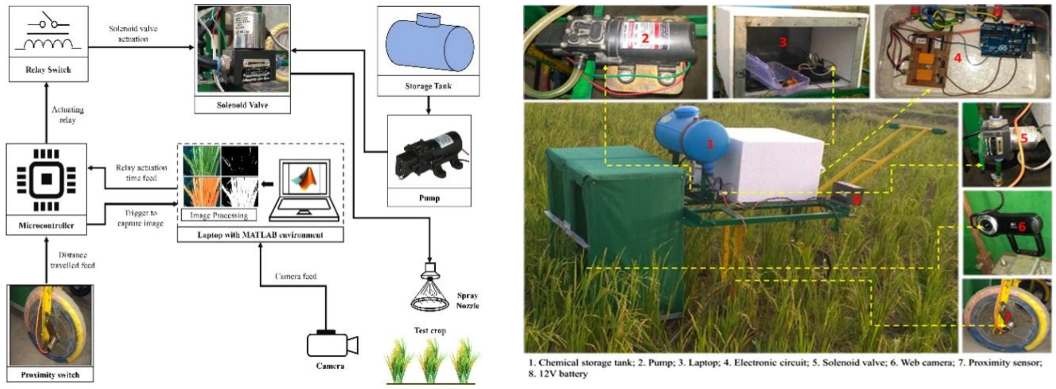

Fig. 7 : Functional block diagram of Variable – rate chemical spraying system.

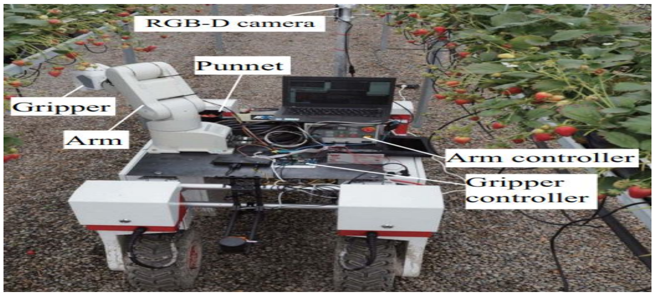

Fig. 8 : First version robot in a strawberry tunnel.

Table 1 : Performance evaluation.

Model	RMSE
SARIMA (1,0,0)(0,1,2)	16.5475
Holt-Winter's Seasonal Method	18.0589
LSTM (Non-Stationary data)	146.8620
LSTM (Stationary data)	7.2780

Yin *et al*. (2020) studied STL-ATTLSTM: Vegetable Price Forecasting Using STL and Attention Mechanism-Based LSTM. The authors proposed the STL-ATTLSTM (STL-Attention-based LSTM) model, which integrates the seasonal trend decomposition using the Loess (STL) preprocessing method and attention mechanism based on long short-term memory (LSTM). The proposed STL-ATTLSTM forecasts monthly vegetable prices using various types of information, such as vegetable prices, weather information of the main production areas, and market trading volumes.The experimental results show that the proposed STL-ATTLSTM model achieved approximately 5–16% higher prediction accuracy (Table 2) than the three benchmark models, with an average RMSE of 380 and an average MAPE of 7%.

Limitations of AI in agriculture

Table 2 : Prediction accuracy measures of proposed model and LSTM.

Vegetable type	LSTM		Attention LSTM		STL-LSTM		STL-ATTLSTM	
	RMSE	MAPE	RMSE	MAPE	RMSE	MAPE	RMSE	MAPE
Cabbage	4972	55%	3602	30%	2033	19%	1196	9%
Radish	271	26%	101	16%	93	13%	105	9%
Onion	122	23%	225	42%	108	16%	134	12%
Pepper	844	8%	914	7%	539	5%	368	3%
Garlic	229	5%	106	2%	218	5%	96	2%
Average	1288	23%	990	19%	598	12%	380	7%

Classical methods of price forecasting are there like Autoregression (AR), Moving Average (MA), Autoregressive Moving Average (ARMA), Autoregressive Integrated Moving Average (ARIMA), Seasonal Autoregressive Integrated Moving- Average (SARIMA), Vector Autoregression (VAR), Vector Autoregression Moving-Average (VARMA) but this methods are less efficient than artificial method of price forecasting *i.e*. Long short term memory (LSTM). In fallowing case study is an comparative study between classical methods (ARIMA and Holt Winter's Seasonal method) and machine learning/artificial method of price forecasting (Long short term memory)

Sabu and Kumar (2020) studied the Predictive analytics in Agriculture: Forecasting prices of Arecanuts in Kerala with objective of Prediction of monthly prices of are canut in Kerala using time-series and machine learning models and the proposed techniques were SARIMA, Holt Winter's Seasonal method and LSTM neural network were used and evaluated. LSTM was found to be a better model in forecasting the prices of Arecanuts in Kerala (Table 1). The one drawback will be the lack of data available for training as LSTM is a deep learning algorithm that requires a lot of data.

Use of artificial intelligence in agriculture has many disadvantages such as incur of high cost, leads to unemployment by replacement of labours in many of the agriculture labour work, no improvement without experience, lacks in creativity, unavailability of accurate data for decision support models, less availability of quality data, less return on investment and more important least awareness to the famers and difficult in social acceptance.

Conclusion

Artificial intelligence has the potential to revolutionize the agriculture industry by providing farmers with valuable insights and data-driven decision-making tools. AI-powered technologies such as precision farming, crop monitoring and predictive analytics can help farmers optimize their yields, reduce costs, and increase profitability. Additionally, AI can help address some of the biggest challenges facing the agriculture industry today, such as climate change, labour shortages and food security. AI in agricultural price forecasting offers the advantage of leveraging vast datasets to identify patterns and factors influencing prices, enabling more accurate predictions and informed decision-making for farmers and stakeholders in the agricultural supply chain. However, there are also some concerns regarding the ethical and social implications of AI in agriculture, such as job displacement and data privacy. Therefore, it is important to carefully consider the benefits and risks of AI in agriculture and ensure that its implementation is done responsibly and ethically.

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